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ABSTRACT

This manual, developed for use by Peace Corps volunteers, attempts to help development counselors to understand the needs of remote-area groups and to provide for those needs through effective self-help projects. The projects covered are those that can solve most effectively, on the village level, the most pressing problems. The manual is written in as nontechnical language as possible and provides background information and step-by-step directions for many projects, illustrated with line drawings. Topics covered by the manual are agronomy, horticulture, entomology, animal husbandry, veterinary medicine, agriculture, home industries, self-help engineering (making tools and equipment), and measurements and conversations. In addition, a background information section is provided for the counselor, dealing with cultural anthropology, sociology, education, and the effects of climate on plant and animal growth. (KC)

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Peace Corps

REMOTE AREAS
DEVELOPMENT MANUAL

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FOREWORD

This manual is a sample of CDCS services available to anyone on a contract basis.

Remote areas development, as treated herein, consists of projects implemented to motivate people to help themselves in the improvement of their living standards, local economies, and the national economies of the countries in which they live.

Self-help projects are the vital part of remote areas development but few persons have had experience with such projects. A search for what to do and how to do it usually is fruitless since most of the available information is too technically advanced to be immediately applicable to villagers.

This manual attempts to correct that situation by enabling the development counselor to understand the needs of a remote area group and to provide for those needs through effective self-help projects.

The projects covered are those which can solve most effectively, on the village level, the most pressing problems. For example, if a village's agriculture is handicapped by a lack of tools, the manual can help the counselor to teach selected villagers to make and use a hand forge to provide the tools for production of ample food.

The manual is generally applicable, for reference and guidance, to any remote area group. However, since problems differ with areas, the counselor will have to adapt projects to what he finds in a specific area.

A key to remote areas development is the selection and training of bright villagers who can teach their own people. If the number of such persons is limited, small extension teams can be formed to instruct in health, education, and economic development.

Most of the undeveloped populations of the world subsist by growing food crops and animals. In suggesting changes one must understand soil conditions, availability of water and nutrients, climate, weather, diseases, and all of the other factors that determine an area's potential for improvement. Many groups produce only enough food for subsistence, and an easy way to make such populations unfriendly is to experiment with new ideas at the expense of their food supplies. A beginner can keep his experiments small and explain that his trials may not succeed but, if successful, could add to the community's income or food supply.

Make sure before you try any project that it does not violate local customs or traditions. A CDCS counselor once suggested the use of oxen and buffalos to pull wooden plows.

We soon discovered that this was taboo because the ancestors lived in the fields and the animals were not allowed to walk there.

See that a big effort does not turn into a big blunder. A recent program to establish vegetable gardens seemed to have considerable merit. Imported seeds were distributed in large numbers. The untested foreign seeds did not produce. Farmers were extremely angry at the host government and at foreign advisers because of lost labor, income and food. The purpose in relating this story is not to discourage but to advise that extreme care is needed to avoid adverse effects.

In promoting cottage industries for remote area populations, one must imagine that the pages of history have been turned back and that modern technology and industrial capabilities no longer exist. If water is carried by hand, perhaps a Persian, or other, water wheel could water crops or animals. The time saved could be used to provide better care of crops through home manufacture of fertilizers by composting.

Improvements can often be made in traditional methods of weaving cloth or making clothing. Introducing a hand loom might improve a village's standard of living. Making pot soap is an industry that could aid health and sanitation. Old rubber tires make good shoes if cut properly and sewn together.

Amazing accomplishments can be achieved by the counselor who can recognize needs that can be resolved by simple projects such as those suggested in this manual. Most of the effective recent development programs have resulted from experimental beginnings on the village level. Let CDCS help to improve living standards for all remote area populations throughout the world. This effort must be carried on if the affluent fraction of humanity is to obtain and keep the good will of the majority.

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Analysis Questions for the Field Counselor

Agricultural

1. What crops, vegetables, animals, or other items form the basis for the population's food supply and/or economy?

2. What topographic, weather, climate, soil, water, wind, and other factors restrict or assist the growth of certain plants or animals?

3. What plants or animals would possibly adjust to area conditions and at the same time benefit the local population's food supply and/or economic situation?

4. What improvements could be made utilizing local assets to improve the area's agricultural production? (Examples might be composting to improve crop production or isolation of sick animals to control the spread of disease).

5. What methods of production, crops, or animals exist in adjoining areas that could be introduced to assist the target area?

6. What are the types of programs that could be attempted on an experimental basis to determine application and population interest? (Examples are home gardens, use of animal power, new hand tools to assist production techniques, and other development).

7. Is there a potential and outlet for cash crop production and/or animal industries?

8. What assistance is available for agricultural loans or development grants from local government or other sources?

9. Would cooperative marketing or production techniques improve the area economy?

10. What area assets are available? From whom can you obtain technical guidance and/or other assistance in the development of agricultural programs?

11. What are the customs and traditions of the population groups that affect agricultural systems?

12. What government controls or other outside restrictions handicap improvement of the general economic situation?

Cottage Industries or Home Industries

1. What cottage industries presently exist?

2. Are basic items needed that could be produced on the village level?

3. What cottage industries would assist the villages in providing more food, clothing, housing or other basic needs? (Examples are weaving looms, brick presses or kilns, and hand forges to produce tools).

4. What raw materials are available to meet the needs of various cottage industrial programs?

5. Do the villagers have certain basic skills that might be applicable to certain types of industries?

6. What are the various possibilities for financing simple machines?

7. Can the needed machines be improvised and constructed on the village level?

8. Is there a potential for cash income resulting from the sale of home manufactured products?

Village Health

1. What are the existing conditions of health and sanitation?

2. If sanitation is poor, what are the primary reasons?

3. Can health education programs be initiated to improve village standards? (Examples are use of latrines, penning of animals, improvement of water supply, etc.)

4. Do local governments provide basic medical assistance? If not, what programs could be initiated?

5. What types of primitive medicine are offered from "quack doctors", sorcerers, etc.?

BACKGROUND

A basic understanding of anthropology, sociology, climatic influences, and education is necessary for anyone hoping to develop community improvement programs. Although the reader will realize that all of these subjects are valuable, he will not fully appreciate their merits until he finds himself wrestling with actual problems in the field. There one learns what programs can succeed. Often people refuse to try something new because of various customs, beliefs, or lack of education. These problems are not necessarily barriers but they must be understood before they can be corrected.

It is very frustrating to have wasted considerable time and effort attempting to introduce a project which, if it had been presented differently,would have succeeded. A knowledge of anthropology, sociology, and the specific area prompts the counselor to learn pertinent facts. Even extensive reading about a group does not replace being there and asking intelligent questions, particularly of village elders, historians, and sorcerers.

Remember that you are present to give assistance and training for only a very short time. The American often makes the mistake of thinking that the best way to develop a community is to do it himself. He reasons that the work will move faster and more smoothly this way because he already has the necessary knowledge; devoting time to developing among the natives the skills needed to enable them to continue the work after he has left would impede progress. However, trained indigenous personnel are an absolute requirement for the continuation of all community development programs.

The American's tendency is to pick up the ball and run with it; thus, when he leaves the game is over. Teaching the people you are helping to carry the ball themselves is a difficult and often avoided task but this is the essence of community development.

CULTURAL ANTHROPOLOGY

Anthropological studies explain how communities solve their problems and how a culture or civilization affects the attitudes of all the individuals living in it.

Most people live in communities and have traditional ways of adjusting to their natural environments and to one another. The ways of life of a community, including its faiths and standards, are solutions to problems of survival.

WHY SOCIETIES ARE ALIKE

All societies provide ways for meeting the fundamental problems. Men feed themselves and their children, reproduce and rear their offspring, and protect themselves and their offspring.

Man's adaptation to the physical world is accomplished not through changing his physical nature, but through society. Animals and plants have made ajustments, over long periods, by the development of radical changes in their very organisms. Hereditary differences meet needs of various environments. But among the races of men, differences in head form and in other physical features are not, in most cases, clearly adaptive. Nor is it clear that mental capacities of races are different. So far as we know, the races of man are equally intelligent and equally capable of solving their problems of living together. Their varying ways of life are, it seems, social and learned differences and not physical and inherited differences. Therefore, man's adjustment to his surroundings is to be studied in custom and institution, not in anatomy and neural structure.

Perhaps the most basic aspect of man's adjustment to the physical world is the relation between population and resources. Any human community is an aggregate of organisms competing with others for food and the other necessities of life. The ways of life of any settlement depend on or are conditioned by the possibilities for livelihood which the environment offers. And, though men always work out ways of feeding themselves, the ways do not remain adequate indefinitely. The increase of population that comes with success in developing natural resources disturbs the balance between resources and population and demands new adaptations. If the tools and methods for exploiting the resources are modified, these modifications in turn bring changes in the institutions and social organization of the people.

Thus, the presence of bison enabled a certain number of Indians to live successfully on the Great Plains. The introduction of the horse, which greatly increased their power to hunt bison, enabled more Indians to live there. With the development of cooperative hunting, when entire tribes depended upon accessible herds of buffalo, soldier societies with police functions grew up among the Indians to control it. When the gun was added to the horse, the bison were hunted so effectively that they were almost exterminated. This reduction of the herds destroyed the Indian economy on the plains, and, with the suppression of warfare by the whites, was largely responsible for the disappearance of soldier societies and military and hunting virtues.

The situation of many a farmer today is quite comparable. In producing large numbers of deprived and insecure migratory laborers, the interaction of these same interrelated factors will be found to be involved: (1) Population increase; (2) accelerated use of limited or marginal resources; (3) strong social and economic pressures from without; (4) technical changes, as in the mechanization of agriculture, and developments in marketing and financing in agriculture; and, (5) corresponding repercussions on the institutions of the farmers and their outlook on life.

HOW THE ANTHROPOLOGIST LOOKS AT SOCIETIES

The anthropologist is helpful because he studies the adjustment of people to their physical environment and to one another. Anthropology had its beginning in speculative philosophy and became a discipline responsible to fact, largely, as one of the earth sciences--a study of human society as one of the elements in a habitat. It is capable of telling us how a simple community makes a living and how social organization and even the will to live are affected by changes in the business of making a living.

In some communities the problem confronting the administrator may be getting enough food. A knowledge of resources, population, and technology may be enough for dealing with that problem. One is not encouraged first to make an exhaustive study of the effects of progressive starvation upon the social institutions. However, a study of the interrelations of technology and social institutions may be of great practical value.

DIFFERENCES BETWEEN SIMPLE AND COMPLEX SOCIETIES

To survive, men must control nature and relations among themselves. Social adjustments among the members of a group are made by means of such organizations as the family, the neighborhood, and economic and political organizations.

Each society has built up, through experiences of its members, a set of values by which they live. Certain actions are considered good and others bad, and these evaluations determine rules of conduct. Such rules consist of obligations, duties, rights, and privileges by which the members of the group are controlled.

The social organization of a people not only regulates the relations of the members but also controls the division of labor necessary for the manipulation of the skills and tools. In some societies the labor is equally divided; in others some individuals are given the pleasant, and others the unpleasant jobs. These differences in tasks are usually associated with status. All of the complex societies, including our own, have some kind of status system. A caste system, such as that of India, is so rigidly fixed that every individual is born to perform a certain task and to occupy a corresponding social position.

There are simple, or undifferentiated, social structures and complex, or differentiated ones. A socially differentiated society is divided into many social institutions, while the simple societies have few social institutions. The family is often the only formally organized social structure that many of these simple communities possess. The more differentiated communities, such as our own, develop different kinds of institutions to perform different social functions. The family system, instead of organizing the economic and political activities of the community, chiefly controls sexual behavior and the early training of the resulting offspring. In primitive societies in Australia, old men dominate the group. In complex communities control is widely distributed among politicians, factory owners, administrators, teachers, professors, soldiers, ministers, and church officials.

In complex societies, the appearance of many kinds of people that are not found in the simpler communities means that there is an increase in (1) specialization, (2) kinds of social status, and (3) individualism.

In specialization there are more activities but fewer of them are performed by any individual. The automobile factory performs a highly specialized activity since it makes but one article, and specialization is carried to its ultimate on the assembly line where the workers perform but one or two of the thousandsof activities necessary to make the automobile. In the development of automotive manufacture the number of activities has increased, while the number of operations performed by the average worker has diminished. A similar specialization occurs among farmers. One region grows corn, another cotton, and still others fruits, vegetables, and other crops. A community living on the production of one crop is dependent on other communities' products.

Social differentiation of a community provides a greater variety of opportunities. This tends to produce individualism. If the variety of situations is such that no two men have the same training or social relations, each man is different.

No study of societies is complete without reference to the universal existence of sacred beliefs and rituals which control communities. These concepts seem to lose their influence as changes become rapid and frequent. "In the old days," said the Indian after he had been put on the reservation, "there was no law; everybody did what was right." He meant that actions, being explained and justified by myth, ritual, and the approval of his fellows, seemed both natural and right. Where a society is left alone long enough, beliefs and customs become harmonious and interdependent. One aspect of contemporary social problems is the break-down of common understandings, especially moral understandings.

In simple agricultural communities such as those of the aborigines of the northern Philippines, or the Pueblo Indians of our own Southwest--at least before the advent of the white man--everyone tends to do part of all the essential things and all men tend to have similar views of life. Anything one man or woman does is much like what another does. In such societies, every man performs the same rituals for the security of his crops and for his inner well-being. The ideas of gods and of good and bad conduct are substantially the same for every person in the community. Therefore, when a student of such a society gets to know one adult in the community, he knows much of all the others.

In complex societies, where the division of labor is high, no one person does more than a small part of the necessary tasks. The people who participate in this division of labor are not homogeneous, as is the case in a self-sufficient primitive society. No man understands it all. The ideas and understandings of any one member, adapted though they be to the mode of life that is there current, do not have the completeness of interrelationship that is characteristic of the habits and customs of people in self-sufficient primitive societies.

The anthropologist, if confronted with a problem of land settlement or a new marketing provision, will study the new system in its relations to the customs of the community. He will ask himself: What was the old program and how does the substitution affect the work, play, or social structure of the community? Assuming the tendency of customs and institutions to be conditioned by one another, he will consider the new feature in terms not merely of its practical efficiency or its theoretical outcome, but of the values and understandings of the people of that community. He will seek to discover what the new device means to the people, and what changes in their customary ways are likely to follow as a result of using it. A change in technology often brings with it changes in the social organization and the system of values of the community.

It appears that a community functions better when its members share common traditions, ideals, and objectives. In primitive societies the members of the community have lived long and intimately together, facing common difficulties and working out solutions in which everyone participates.

SOCIOLOGY

It has often been said that the physical or "natural" sciences have been developed to a high state but that they are just as capable of wrecking as of creating civilization. What is needed, according to this view, is a social science that will show us how to use our knowledge for the good of man. But the social sciences are very young, and to a considerable extent they have been confined to the classroom and the professor's study. Can they be applied to the problems of the everyday world? Here is an attempt to explore the possibilities of using sociology in the study of rural problems.

Sociology has been developing for only a little over a generation, but during that short period it has been organized into fairly concrete fields of study and investigation focused upon social problems of which the general public has become conscious. The following specific fields of teaching and research, each of which will be described later, probably represent sociology as well as any: Social organization; population study, or social demography; social ecology, or human geography; cultural or social anthropology; social psychology; social pathology.

SOCIAL ORGANIZATION

The study of social organization is the heart of sociology, for social organization constitutes the formalized machinery by which people live. Social organization in rural life is in many ways similar and in a number of ways dissimilar to that in urban life. Each rural grouping has a pattern conditioned not only by geography and the means of transportation and communication but by inherited ethnic, religious, and economic social patterns. Neighborhoods, villages, institutional and service groups, including families, schools, churches, libraries, and health, recreational, and welfare agencies; class and commodity groupings; and even political groups, all constitute forms of social organization. People measure their social standing in terms of the extent to which they are able or are permitted to help operate these pieces of social machinery; and since everyone desires an acceptable social status, some of the deepest issues of rural welfare are involved in the problems of participation in social organizations.

The impact of the world at large on rural life is steadily increasing. It is important to know to what extent local organizations contribute to the economic, social, and psychological stability, well-being, and contentment of rural people. Their major concern is with comparatively local community organizations. Development programs should recognize this.

POPULATION, OR SOCIAL DEMOGRAPHY

Demography (from demos, people, and geography) or population analysis, is important to the economist, the political scientist, and the geneticist. It deals with the numbers, distribution, and composition of populations and ventures predictions concerning population trends and their relationships to the physical, economic, and social environment.

Rural populations throughout the world bear peculiar relationships to national populations and to national economic and social structures. The urbanization of society has been in process for generations and has stimulated an almost constant net flow of population from farms to towns and cities, out of agriculture into industrial, commercial, and professional occupations. The rural birth rate nearly everywhere is higher than the urban, and in many instances is highest in areas with the poorest natural resources and the lowest standards of living. Because persons born and reared in rural areas, including areas with poor natural resources and poor economic and social opportunities, will continue to furnish workers and citizens to other segments of the population and to the economic and social life of the nation as a whole, a nation must be concerned with the character, composition, and opportunities of its rural population.

SOCIAL ECOLOGY, OR HUMAN GEOGRAPHY

Social geography or ecology is the study of the way people distribute themselves over the land in developing and utilizing natural resources and in response to cultural and social forces. Land utilization strongly affects the total social structure of a region. The amount of land per farm determines the spacing of the rural population and consequently affects all social institutions and contacts. Community life, institutions, and the levels of living of a people are influenced by the natural resources of the area. Ownership and control of land condition social welfare. Unless tenure is relatively permanent and secure, the making of profits from efficient use of land will not guarantee the user's welfare.

SOCIAL ANTHROPOLOGY

Not least among the natural resources of a society or a nation is its social heritage. In a rapidly changing society this heritage may be lost. It is not possible for any society to break completely the ties between its past and present, but it is easy to fail to recognize the influence of these ties. Such failure is quite common, especially among those who deal with more exact and measurable phenomena. It is natural that new traits of culture, especially when they are physical or economic and therefore easily observed, should obscure the presence of old traits that lie deeply hidden in people's attitudes and their value judgments. These attitudes and judgments are the most persistent things in human experience. They may constitute the inertias of a society which prevent change and preserve "sacred" tenets of the group. The more rationalized--that is, the more scientific, efficient, and planned--agriculture becomes, the more important it is to understand these forces of inertia that may thwart complete rationalization or expertization of economic, political, and social programs.

The folk culture in a simple society is its most treasured possession. This is probably true of even the most complex societies, though people are not aware of it. When change is very rapid and diverse, however, the treasured possessions of culture are jostled out of their place in the life of the group because of the competition of new elements that temporarily obscure them. In our modern rural society, we undoubtedly desire many of the new things, but we would like to obtain them without sacrificing the treasures of social heritage. We want not only the economic but the social and psychological security people had when self-sufficient agriculture prevailed. We want the richness of rural life that many less commercial agricultures have because of their folk art, music, drama, recreation, and other community activities; we want the personality and values which we think grow only out of family, neighborhood, and community life; but we do not want the continuation of a large amount of irksome labor, the isolation, and the low standards of living that can be eliminated by modern science, business, and technology.

We cannot attain this happy combination of past and present unless we understand the folk, as well as the scientific, processes. We must know how far and how fast improvements can be made in the standard of living by artificial stimulation or by demonstration. Cultural anthropologists have for decades been studying cultures of relatively simple societies. Their techniques are applicable to analysis of more complex societies.

SOCIAL PSYCHOLOGY

While the cultural anthropologist studies human behavior as a complex whole in terms of folkways, customs, traditions, and group values, the social psychologist attempts to understand these cultural processes as they manifest themselves in individual human behavior.

Social psychology deals with the way customs, traditions, institutions, and unique life experiences are reflected in the attitudes and opinions of members of a group. It also attempts to analyze and understand the operation of public opinion as it functions in collective behavior.

Social psychology helps us to predict attitudes toward development programs and the economic and social adjustments which these programs seek to effect. It tells us how public opinion and democratic processes can be made to work in programs that are promoted, at least partly, and in some cases quite dominantly, from above; what is happening to individual initiative and enterprise under such programs and under public relief programs; and what is happening to the old rural neighborhood and folk attitudes and habits under the impact of mechanization and commercialization.

Because of the slowness with which new elements of culture have penetrated rural areas, behavior and ideas have prevailed there long after they have changed in urban centers. A thorough understanding of the values and inertias of rural institutions is essential to an understanding of how they can be changed.

SOCIAL PATHOLOGY

Social pathology is the study of social maladjustments. In rural districts crime has always been relatively slight and pauperism almost absent, but poverty has been much more widespread than is commonly known. If rural families living in poverty do not resent this status, it ill behooves the sociologist or anyone else to be unduly worried about them unless the existence of such conditions jeopardizes other families or handicaps the future generation being born and reared in these homes.

Rural slums have been developing through a number of generations, but this has not been obvious to the general public, or even to the rural public. Inadequate rural houses existing by the thousands have not been so concentrated geographically as to be obvious to the passer-by. Rural unemployment has most often existed in terms of underemployment or ineffective employment and has not been recognized because of the relatively self-sufficient mode of life on the farm. Consequently, little attention has been given to the problem of farm unemployment. It is too often assumed that there is a steady stream of people moving up the agricultural ladder from laborer to tenant to owner. There is considerable evidence that there is an ever-increasing number of persons who are being stalled on the lower rungs of the ladder and many who are descending.

EDUCATION

The function of education has always been to prepare people for happy and successful living in the communities of which they are a part. If education is to be of real service to remote and rural communities, we must cease to be awed by traditional subjects and procedures and teach essentials.

Education has existed in all societies. In many ways the educational procedures of primitive men were more sensible and more effective than the schools of today. The ancients knew what they wanted and went about it vigorously and directly. The boys learned warfare, hunting, and hardihood as well as many manual arts. The girls learned cooking, weaving, and other women's skills and duties. Both sexes were steeped in the traditions, morals and ideals of their group. The societies of adolescents and the spectacular and often prolonged initiation ceremonies were for the sole purpose of preparing young people for their coming responsibilities as members of the tribe. American Indians, Polynesian islanders, and African tribesmen went to school arduously and on the whole successfully centuries before the little red schoolhouse came into being in Europe and North America.

The formal schooling of western Europe and modern America grew from the same need as the home training and societies of adolescents of the ancient tribes. As life became more complex with the growth of reading and writing and science and mechanics, the duties of the school became more onerous and time-consuming. During the last century or two, with the upsurge of science and the industrial revolution, the obligations of the school became overwhelming. It was necessary to divide the tasks and classify the studies. Specialists were called in to teach each subject: reading, figuring, crafts, traditions and morals, foreign languages, the fine arts, sciences and mechanics. Some of this education was given in the home, some of it by priests and preachers, most of it in special buildings called schools. About each department of learning grew up a special profession of teachers and special textbooks, traditions, and feelings of prestige.

Today most of us do not talk about the sacredness to education of any given subject. Instead, with the same directness as the primitives, we are trying to teach what members of a society need to know.

RURAL SCHOOLS AND THE NATION

What happens in rural schools concerns all of us. If we can devise good educational practices anywhere, these may be expected in time to influence the whole school system. To a great degree the future citizens of cities are being educated in rural communities. Urban populations are not reproducing themselves, and rural regions are continuing to produce surplus populations which are moving into cities.

How then can we plan the rural school so that it will give the villager what he needs for life in his community and also for citizenship in the modern complex world? The problem is to give him the basic tools of knowledge and to get him to put these tools to use for his own growth and for the improvement of the community in which he lives.

READING, WRITING, AND ARITHMETIC

No person is prepared to take his place in the modern world without some competence in reading, writing, and arithmetic but remember that language and numbers are tools and not ends in themselves. The chief fault in the teaching of them is that lessons become so formalized that the pupil scarcely understands why he is learning. Despite the great amount of time devoted to these primary subjects, a shocking number of children--especially in rural regions--do not acquire even an elementary knowledge of them.

If a person really learns to read and puts his knowledge into practice, he can care for all the rest of his academic education by his own efforts. The difference between educated and uneducated people is largely the difference in the range and understanding of their reading. Abraham Lincoln was one of the best educated of men despite meager schooling because he read so avidly. Almost all of the subject matter of elementary schools may be regarded as practice in reading and it should be thought of not as something to be had from a special class or a special set of textbooks, but as the means of mastery of all the subjects and projects which make up life.

COUNTRY LIFE AS GENERAL EDUCATION

The rural pupil should be acquainted with handcrafts and the processes of nature, not necessarily as vocational subjects but as essential tools quite as general in their use as language or arithmetic. Ability to use one's hands is a fitting supplement to ability to use one's wits. Manual arts run the whole gamut from homely hand labor to high expression in art and music. Hand skills are a part of any person's preparation for life. Nature study, through instruction in gardening, animal husbandry, and health, should also be stressed.

Manual dexterity and the understanding of nature are so generalized that they may be introduced better through related activities than through formal courses. School lessons attempted in health or hygiene have proved to be almost as deadly as the ills they were supposed to correct. Stimulating activities involving manual dexterity and natural processes can easily be arranged by a resourceful teacher. They do not require elaborate or expensive equipment. The less formal the equipment the better, since the aim is to stir up the creative impulse and to develop resourcefulness. This is especially true for rural children whose problem often is to create utility or beauty from meager materials.

If true education is learning from doing one task how to use similar processes in other problems, then hand work and activities with nature are almost necessarily educational. One can scarcely use a saw or a hammer without realizing that it is usable for many ends; using clay, cloth, or a musical instrument is general rather than rote. Similarly in the processes of nature variety rather than routine is the rule. The planting of a school garden, for example, involves so many variables (seed, soil, fertilizer, weather, parasites) that it is almost impossible for it to become routine.

These hand and nature activities tend to break down the rote learning of other subjects. When a child sees multiplication at work through the breeding of rabbits, he cannot keep from realizing that arithmetic is something more than a lesson. Reading becomes an active tool--not simply an exercise--when it is used in finding out how to plant flowers or cultivate vegetables. Figuring comes alive for a boy when he measures off a garden plot or computes the yield from seed corn.

If rural children can gain some competence in these basic skills and can put them to active use, they will have some preparation for happy and successful living. The reason these skills are not mastered is that instead of generalized study and practice of a few broad topics, the school attempts to cram a great multitude of lessons into the brief days. Subjects are artificially divided into fragments which are rehearsed in tiny sections. In many rural schools one or two teachers rush through a whole day made up of lessons of less than 15 minutes each. No wonder that teachers, driven by fantastic schedules of rote lessons, fail to offer real education in any subject or that children, hurried from class to class, come to regard school as a place for reciting rather than for learning.

All this may seem to be arguing the obvious. It is. But thousands of schools today are not attempting to give any application to the simplest of routine skills. Millions of children are merely learning scholastic tricks--just like parrots or trained fleas.

The school today has one other significant task. Not only must it give its pupils knowledge and skill, it must in some way get this learning into practice by the children and by the community. The general welfare is today largely a question of education. Especially in rural regions the school is often the only organized social force able to exert general influence.

In this new world of science and democracy, education not only has to encompass new realms of learning but also has to assume much of the social responsibility previously cared for by the church, the home, and other constituted authorities. If it were possible to build afresh a well-balanced society, the designers of it would probably hesitate to concentrate so much responsibility in a single institution. But in many countries today, and especially in rural areas, there is no other institution to which we can turn.

In health education the relation between teaching and the practices of the community is immediately apparent, for health cannot be treated as an individual matter. Hookworms can be avoided only by general sanitary facilities. Typhoid is spread by impure water or bad food, no matter how careful each individual tries to be. Malaria flies on the wings of mosquitoes from house to house unless swamps are drained or screens carefully used. Tuberculosis, diphtheria, measles, spread from person to person. Public action and community cooperation are necessary if a village or countryside is to keep well. The school, as the emissary of modern knowledge, is the natural rallying ground for information and for action toward better health for the individual and for the neighborhood.

Farming is another example of the natural transition from the classroom to the field. The processes of nature about which the child learns in school are the foundation of agriculture. The verbal learning takes effect only as it is applied. Of course small children cannot undertake to change the habits of their parents. But the school can help both parents and children to profit from modern knowledge.

The school may become the focal point for cooperative action by many governmental agencies--public health, home demonstration, farm extension, library service. Coordination is badly needed in these public services which mean so much to rural development but which suffer from the natural tendency of each to engage busily in its own activities without regard for the work of the others or the general needs of the communities.

The community is the practice ground for the school. The school succeeds only as it contributes to the community as well as to the skill and knowledge of individual pupils.

CLIMATE

TEMPERATURE DISTRIBUTION

The distribution of temperature over the world and its variations through the year depend primarily on the amount and distribution of the radiant energy received from the sun in different regions. This in turn depends mainly on latitude but is greatly modified by the distribution of continents and oceans, prevailing winds, oceanic circulation, topography, and other factors.

In the winter of the Northern Hemisphere the poleward temperature gradient (that is, the rate of fall in temperature) north of latitude 15° is very steep over the interior of North America. The temperature gradient is also steep toward the cold pole over Asia. In western Europe, to the east of the Atlantic Ocean and the North Atlantic Drift, and in the region of prevailing westerly winds, the temperature gradient is much more gradual. In the winter of the Southern Hemisphere the temperature gradient toward the South Pole is very gradual because continental effects are largely absent.

In the summers of the two hemispheres--July in the north and January in the south--the temperature gradients poleward are very much diminished as compared with those during the winter. This is especially marked over middle and higher northern latitudes because of the greater warming of the extensive interiors of North America and Eurasia than of the smaller land areas in middle and higher southern latitudes.

DISTRIBUTION OF PRECIPITATION

Whether precipitation occurs as rain or snow or in the rarer forms of hail or sleet depends largely on the temperature climate, which may be influenced more by elevation than by latitude, as in the case of the perpetually snow-capped mountain peaks and glaciers on the Equator in both South America and Africa.

The quantity of precipitation is governed by the amount of water vapor in the air and the nature of the process that leads to its condensation into liquid or solid form through cooling. Air may ascend to great elevations through local convection, as in thunderstorms and in tropical regions generally; it may be forced up over topographical elevations across the prevailing wind direction, as on the southern or windward slopes of the Himalayas in the path of the southwest monsoon of India; or it may ascend gradually in migratory low-pressure formations such as those that govern the main features of weather in the United States.

The areas of heaviest precipitation are generally located in tropical regions where, because of the high temperature, the greatest humidity and evaporation occur--although only where conditions favor condensation can rainfall occur. Outstanding exceptions are certain regions in high latitudes, such as southern Alaska, western Norway, and southern Chile, where relatively warm moist winds from the sea undergo forced ascent over considerable elevations.

In marked contrast to the rainy regions just named are the dry polar regions where the humidity is always very low because of the low temperature and very limited evaporation. The dry areas in the subtropical belts of high atmospheric pressure (in the vicinity of latitude 30° on all continents, and especially from the extreme western Sahara over a broad, somewhat broken belt to the Desert of Gobi), and the arid strips on the lee sides of mountains on whose windward slopes precipitation is heavy to excessive, are caused by conditions which, even though the temperature may be high, are unfavorable to the condensation of whatever water vapor may be present in the atmosphere.

NORTH AMERICA

North America is nearly all within middle and northern latitudes. It has a large central area in which the continental type of climate with marked seasonal temperature extremes is to be found. Its western coast has moderate midsummer temperatures in marked contrast to those prevailing in the interior east of the mountains. The mild midwinter temperatures in the coastal areas also contrast with the severe conditions from the Great Lakes region northward and northwestward.

In the West Indies, temperatures are subtropical; and in Mexico and Central America, climatic zones depend on elevation, ranging from subtropical to temperate in the higher levels.

The prevailing westerly wind carries the continental climate eastward over the United States, so that the region of maritime climate along the Atlantic Ocean is very narrow.

The northern areas are very cold; but the midwinter low temperatures fall far short of the records set in the cold-pole area of northeastern Siberia, where the vast extent of land becomes much colder than the partly ice-covered area of northern Canada.

From the Aleutian Peninsula to northern California west of the crests of the mountains, there is a narrow strip where annual precipitation is over 40 inches; it exceeds 100 inches locally on the coast of British Columbia. East of this belt there is an abrupt decrease in precipitation to less than 20 inches annually over the western half of the continent from lower California northward, and even less than 5 inches in parts of what used to be called the "Great American Desert," in the southwestern part of the United States.

In the eastern part of the continent--that is, from the southeastern part of the United States northeastward to Newfoundland--the average annual precipitation is more than 40 inches. Rainfall in the West Indies, southern Mexico, and Central America is generally abundant. It is very spotty, however, varying widely even within short distances, especially from the windward to the leeward sides of the mountains.

SOUTH AMERICA

A large part of South America is tropical. The remaining rather narrow southern portion is not subject to the extremes of heat and cold that are found where wide land areas give full sway to the continental climate with its hot summers and cold winters, as in North America and Asia. Temperature anomalies for a given latitude are to be found mainly high in the Andes from the Isthmus of Panama to Cape Horn.

The Antarctic Current and its cool Humboldt branch skirting the western shores northward to the Equator, together with the prevailing on-shore winds, exert a strong cooling influence over the coastal regions of all the western countries of South America except Colombia. On the east the southerly moving Brazilian current from tropical waters has the opposite, or warming, effect except along southern Argentina.

In the northern countries of South America the sharply contrasted dry and wet seasons are related to the regime of the trade winds. In the dry season (corresponding to winter in the Northern Hemisphere) these winds sweep the entire region, while in the wet season (corresponding to summer in the Northern Hemisphere) calms and variable winds prevail. In the basin of the Amazon River the rainfall is related to the equatorial belt of low pressure and to the trade winds, which give the maximum amounts of rainfall in the extreme west, where they ascend the Andean slopes.

The desert areas on the west coast of South America, extending from the Equator southward to the latitude of Santiago, are due primarily to the cold Humboldt or Peruvian Current and upwelling cold coastal water. The moist, cool ocean air is warmed in passing in over the land, with a consequent decrease in relative humidity, so that the dew point is not reached and condensation of vapor does not occur until the incoming air has reached high elevations in the Andes, where temperatures are very much lower than along the coast.

In southern Chile the summer season has moderate rainfall, and winters are excessively wet. The conditions that prevail farther north are not present here, and condensation of moisture from the ocean progresses from the shores up to the crests of the Andes. By the time the air passes these elevations, however, the moisture has been so depleted that the winds on the leeward slopes are dry, becoming more and more so as they are warmed on reaching lower levels. The mountains can be looked upon as casting a great "rain shadow"--an area of little rain--over southern Argentina.

EUROPE

In Europe there is no extensive north-south mountain system such as is found in both of the Americas, and the general east-west direction of the ranges in the south allows the conditions in the maritime west to change rather gradually toward Asia. Generally rainfall is heaviest on the western coasts, where locally it exceeds 60 inches annually, and diminishes toward the east--except in the elevated Alpine and Caucasus regions--to less than 20 inches in eastern Russia.

There is a well-defined rain shadow in Scandinavia, with over 60 inches of rain in western Norway and less than 20 inches in eastern Sweden.

Over much of Europe rainfall is both abundant and rather evenly distributed throughout the year. The chief feature of seasonal distribution of precipitation is the marked winter maximum and the extremely dry, even droughty, summers in most of the Mediterranean lands.

Isothermal lines have the general direction of the parallels of latitude except in winter, when the waters of the western ocean, warmed by the Gulf Stream, give them a north-south trend. Generally there are no marked dips in isotherms due to elevation and continental type of climate such as are found in North America. In Scandinavia, however, the winter map shows an abrupt fall in temperature from the western coast of Norway to the eastern coast of Sweden and thence a continued fall eastward, under a type of exposure more and more continental in contrast to the oceanic exposure on the west.

ASIA

The vast extent of Asia gives full opportunity for continental conditions to develop a cold area of high barometric pressure in winter and a low-pressure, hot area in summer, the former northeast of the Himalayas and the latter stretching widely from west to east in the latitude of northern India. These distributions of pressure give to India the well-known monsoon seasons, during which the wind comes from one direction for several months, and also affect the yearly distribution of rainfall over eastern Asia.

In winter the air circulation is outward over the land from the cold pole, and precipitation is very light over the entire continent. In summer, on the contrary, there is an inflow of air from the oceans; even the southeast trade winds flow across the Equator and merge into the southwest monsoon which crosses India. This usually produced abundant rain over most of that country, with excessively heavy amounts when the air is forced to rise, even to moderate elevations, in its passage over the land. At Cherrapunji (4,455 feet), on the sourthern side of the Khasi Hills, in Assam, the average rainfall in a winter month is about 1 inch, while in both June and July it is approximately 100 inches. However, this heavy summer rainfall meets an impassable barrier in the Himalaya Mountains, while the much lighter summer monsoon rainfall over Japan and eastern Asia does not extend far into China because of lesser elevations. Consequently, while the southeast quadrant of Asia, including the East Indies, also with monsoon winds, has heavy to excessive annual rainfall, the remainder of the continent is dry, with vast areas receiving less than 10 inches annually.

North of the Himalayas the low plains are excessively cold in winter and temperatures rise rather high in summer. At Verkhoyansk in the cold-pole area, and north of the Arctic Circle, the mean temperature in January is about -59° F. and in July approximately 60°; the extreme records are a maximum of 94°, from readings at 1 p.m., and a minimum of -90°.

In southwestern Asia the winter temperature control is still the interior high-pressure area, and temperatures are generally low, especially at high elevations; in summer at low elevations excessively high maxima are recorded, as, for example, in the Tigris-Euphrates Valley.

AFRICA

Africa, like South America, lies very largely within the Tropics; and there, too, temperature distribution is determined mainly by altitude. Moreover, along the southern portion of the western coast the cool Benguela Current moves northward, and on the eastern coast are the warm tropical currents of the Indian Ocean, which create conditions closely paralleling those found around the South American Continent. In the strictly tropical areas of Africa conditions are characterized by prevailing low barometric pressure, with convectional rainfall and alternate northward and southward movement of the heat equator, while in both the north and the south the ruling influences are the belts of high barometric pressure.

Except in the Atlas Mountains in the northwest, where the considerable elevations set up a barrier in the path of the trade winds and produce moderate rainfall, the desert conditions typified by the Sahara extend from the Atlantic to the Red Sea and from the Mediterranean southward well beyond the northern Tropic to about the latitude of southern Arabia.

South of the Sahara, rainfall increases rapidly, becoming abundant to heavy from the west coast to the central lakes, with annual maxima of over 80 inches in the regions bordering the eastern and western extremes of the Guinea coast. This marked increase in precipitation does not extend to the eastern portion of the middle region of the continent, where the annual amounts received are below 40 inches and decrease to less than 10 inches on the coasts of Somaliland. Also to the south of the central rainy area there is a rapid fall in precipitation toward the arid regions of Southwest Africa, where conditions are similar to those in Somaliland.

The heavy rainfall over sections of Ethiopia from June to October, when more than 40 inches fall and bring the overflowing of the otherwise arid Nile valley, is one of the earth's outstanding features of seasonal distribution of rainfall. Moist equatorial climate is typified by conditions in the Belgian Congo; arid torrid climate by those of Egypt and the Sahara; and moderate plateau climate by those found in parts of Ethiopia and the British possessions to the southward.

AUSTRALIA

Because of the location of Australia, on both sides of the southern Tropic, temperatures far below freezing are to be found only in a small part of the continent, in the south at high elevations. In the arid interior extreme maximum temperatures are very high, ranking with those of the hottest regions of the earth.

CLIMATE AND LIVESTOCK PRODUCTION

Although climate primarily affects animals indirectly through its influence on the quantity and quality of the plant products used as feed, it also affects physiological functions involved in the maintenance of normal body temperature under diverse weather conditions. There are optimum climatic conditions under which different classes of livestock will develop and produce best within the limits of their inherent capacity.

With few exceptions, the types of farm animals in the United States originated on other continents. Vast numbers of breeding stock have been imported from the Old World and distributed throughout this country. Through trial and error and adjustment of types and breeds to various environments, nutritional planes, and economic conditions, regional distribution of domestic types and breeds is resulting as the areas adapted to each type become better defined.

INDIRECT AND DIRECT EFFECTS OF CLIMATE

The rate of growth from birth to about 30 months of age of beef cattle is directly influenced by seasonal changes in weather due to their effects on pasturage. The long drought characteristic of many parts of the Tropics materially reduces milk production by greatly reducing the pasturage available and affecting the nutritive value of the grasses. When dairy cattle are properly fed during the drought season there is no appreciable drop in production. Climate also influences the production of dairy cows more directly. Larger eggs are produced in the northern than in the southern latitudes by pullets of the same breed, and summer eggs are smaller than winter eggs from the same birds. In the Philippines rainfall also influences egg production. On a year-round high plane of nutrition maximum production is attained during the dry season and minimum production during the wet season.

Rainfall is also an important factor in the case of sheep. It is generally recognized that the Merino as a breed is not naturally adaptable to moist conditions. On the other hand, British mutton breeds thrive best in a moist, cool climate. Apart from their effects on pasturage, temperature and rainfall have a pronounced effect upon the distribution and development of the British breeds of sheep. In England the denser sheep populations are found in areas with 20 to 40 inches of rainfall annually. In South Africa, the best wool-growing areas have less than 20 inches of rainfall and the production of fat lambs is possible only in areas with more than 30.

EFFECTS OF SEPARATE CLIMATIC FACTORS

Climate is a complex thing, including such factors as temperature, humidity, atmospheric pressure, wind velocities, and amount of light. Each of these factors affects life processes, but under natural conditions it is seldom possible to determine their effects separately. For this reason, when scientists study the effects of climatic factors they take one at a time and try to hold all the other factors of the environment constant, varying only the one under investigation. Since temperature is perhaps the most important climatic factor in livestock production, and certainly the easiest to control in experiments, considerable work has been done on the effects of temperature on farm animals.

TEMPERATURE

With dairy cattle, as the atmospheric temperature increases from 40° to 95° F., milk production gradually drops from 29 to 17 pounds a day. Purebred European dairy cattle imported into the Tropics produce, on balanced rations, only 56 percent of their apparent capacity. The optimum stable temperature for dairy animals is about 50°. Holstein cows in Singapore in an air-conditioned barn kept at 70° produced an average of 24 pounds of milk a day as compared with a production of 9 pounds for a similar group in an open, ventilated barn exposed to tropical temperature.

High atmospheric temperatures have a profound effect on the reproductive as well as the productive efficiency of livestock. In the experiment just cited, 58 percent of the cows in the air-conditioned barn conceived within 5 months as compared with only 25 percent in the ventilated barn. The breeding efficiency of males in particular is affected by high temperatures. Proved (aged) sires at the southern experiment stations of the United States Department of Agriculture had an average fertility of 36 percent while those in the western and northern stations averaged 49 percent. Sterility during the hot months of a large percentage of bulls of the exotic (imported) breeds in South Africa is attributed to the high temperature. High summer temperatures lower the vitality of the spermatozoa in the ram and, if continued several weeks, cause degeneration of the reproductive organs, resulting in sterility. These researches explain in part why breeding is seasonal with some classes of livestock, especially sheep. In the United States ewes of the major breeds come in heat and breed during October and November.

LENGTH OF DAY AND SUNLIGHT

Length of daylight also affects the fertility of farm animals, thereby influencing the breeding season. Increased fertility by the use of lights in poultry houses to stimulate production during the winter months when daylight is limited and egg production is normally low is a common practice on the commercial poultry farm. When cattle are moved from the shade and exposed to strong sunlight on a summer day, their respiration rate and body temperature rise, indicating increased difficulty in disposing of body heat. This is reflected in grazing habits; less time is spent grazing in an open pasture on a bright, calm summer day than on an overcast day. Cattle graze more on bright summer days with a gentle breeze than when the air is still. European types of cattle are adapted to certain areas in Puerto Rico because of the rather constant Caribbean trade winds there.

OVERCOMING CLIMATIC DISADVANTAGES BY BREEDING

Some of the ill effects of high temperature and humidity can be overcome by clipping but the lack of adaptability of certain types of animals to tropical climatic conditions, as evidenced by discomfort, low production and degeneration in type, can best be overcome by breeding. There are distinct differences between species and breeds in ability to withstand climatic conditions. The superior adaptability of the Brahman (Zebu) types of cattle to tropical climatic conditions is being utilized in various ways. In Jamaica when the low milk-producing but highly adaptable Montgomery (Sahiwal) type of Zebu was crossed with European dairy cattle, the offspring were frequently much better producers than their parents. Comparable results have been obtained with crossbred beef cattle in South Africa, Australia, and the Gulf coast region of the United States. Cross breeding of Brahman with standard beef breeds for resistance to subtropical climatic conditions has been a general practice in the Gulf coast region for more than a generation. The U.S. has developed the Beefmaster (Brahman, Hereford, and Shorthorn), Brangus (Brahman and Angus), Charbray (Brahman and Charolaise), and Santa Gertrudis (Brahman and Shorthorn).

Improved dairy types of cattle adaptable to tropical and subtropical climatic conditions are being developed in India with pure Brahman (Zebu) stock, while in Brazil, Jamaica, and the Philippines new Brahman-European crossbred types are appearing. That dairy strains of Brahman cattle have not been used in the continental United States to improve the heat-resisting ability of dairy cattle in the South is due partly to the availability of the Jersey, which possesses more heat tolerance than some of the other breeds in the United States. Tests at Jeanerette, La., show that this breed has a heat tolerance somewhat superior to the one-quarter Brahman, three-quarters Angus crossbred. The preponderance of Jersey-bred cattle in the Southern States may be explained on this basis.

The pig under domestication is usually well housed and therefore not subjected to extreme climatic conditions in the Temperate Zone. However, Texas summer temperatures reduce the rate of gain of hogs. In the Philippines a new breed, the Berkjala, a cross between the Berkshire and the native Jalajala, is being developed as a lard-type hog to resist tropical climatic conditions.

Farm animals usually are kept in an artificial environment. Much of the success of the livestock industry depends upon our ability to furnish a favorable environment in which livestock can develop and produce to the limit.

EFFECTS OF CLIMATIC FACTORS ON GROWING PLANTS

Climate largely determines the type of vegetation that grows naturally in any part of the world and the kinds of agricultural production that are possible. The three most important factors in climate from the standpoint of plant response are temperature, water supply, and light. Temperature is the main factor that determines where native species or crop plants can be grown in great belts north and south of the Equator. Precipitation or water supply is the most important factor in determining the distribution of plants and crops within these great belts of somewhat similar temperature conditions. Light varies greatly in intensity in different areas, and the length of daily illumination varies in different regions and at different seasons of the year. Both light intensity and the length of the daily illumination period profoundly affect plant behavior.

Other elements of climate are less important from the standpoint of crop production. Wind increases the water requirement of plants. Hailstorms, tornadoes, or hurricanes may destroy crops locally. Near salt water, the salt spray may be destructive to many forms of vegetation.

All of these elements of climate are interrelated in their effect on the plant organism. Temperature and light affect the water requirement. The available moisture supply greatly influences the effects of high temperatures and light intensities. Although these elements of climate are discussed separately, the reader should keep in mind that the plant is a complicated organism, affected by all factors in its environment, nutritional as well as climatic, and that these effects are usually interrelated in plant response. The following values for latitude, longitude, and elevation are suggested for determining the time at which plants of the same species will flower:

1. For each degree of latitude north or south of the Equator, flowering is retarded 4 calendar days.
2. For each 5 degrees of longitude, from east to west on land areas, flowering is advanced 4 calendar days.
3. For each 400-foot increase in altitude, flowering is retarded 4 calendar days.

TEMPERATURE AND PLANT GROWTH

Temperature influences every chemical and physical process connected with plants--solubility of minerals; absorption of water, gases, and mineral nutrients; diffusion; synthesis, growth and reproduction. Thus temperatures delimit the areas of successful production of most agricultural crops. Such well-defined areas as the Cotton Belt, the Corn Belt, the winter and spring wheat areas, and the Michigan fruit belt are determined essentially by temperatures. This limiting influence on crop distribution results primarily from (1) too short a period of favorable temperature for crop maturity; (2) unfavorably high or unfavorably low growing-season temperatures for proper development of the crop; (3) occurrence of temperatures, either high or low, that cause injury or death to growing plants; (4) winter temperature conditions that injure or kill dormant plants; and (5) temperature conditions particularly favorable to the development of injurious diseases or insect pests.

In its evolution the plant kingdom has become adapted to a wide range of temperatures. There are few places on earth too hot or too cold to sustain some form of plant life. Certain blue-green algae thrive in hot springs where the water is constantly near the boiling point. Plants of arctic regions survive where winter temperatures reach -90° F. Many plants can adapt themselves to great extremes of temperature by entering resting stages. Dormant trees that withstand -65° F. in winter are killed when they are in summer growing condition by temperatures a few degrees below freezing. Dried seeds and spores withstand temperatures of liquid air and liquid oxygen. Spore stages of certain fungi can survive temperatures up to 130° C. (266° F.).

The temperature range within which growth takes place is much more limited than that within which plants in inactive stages can survive. Mention has already been made of the hot-springs algae that grow at temperatures of about 930° C. (199.4° F.). At the other extreme are fungi that develop in cold storage at about -6° C. (21.2°F.) and certain marine algae that complete their life cycle in sea water below 0° C. (32° F.). These, however, are exceptional cases, interesting because they show the enormous adaptability of plant protoplasm. By far the greater number of both higher and lower plants are capable of carrying on growth only within a comparatively narrow range, from about 0° C. (32° F.) to about 50° C. (122° F.).

For each species and variety there is a minimum and maximum growth temperature. Between these limits there is an optimum temperature at which growth proceeds with greatest rapidity. These three points are called the cardinal growth temperatures. At the minimum point growth proceeds very slowly. From somewhat above the minimum to the optimum, the rate of growth follows van't Hoff's law; that is to say, for every 10° C. (18° F.) rise in temperature the rate of growth approximately doubles. Above the optimum, the growth rate falls off rapidly until it stops. Thus the optimum and maximum points are closer together than are the optimum and minimum.

These cardinal growth temperatures vary considerably among the different kinds of plants. With typical cool-season crops, such as oats, rye, wheat, and barley, these points are all comparatively low--minimum 0°-50° C. (32°-41° F.), optimum 25°-31° C. (77°-87° F.), and maximum 31°-37° C. (87.8°-98.6° F.). For hot-season crops, such as melons and sorghums, the temperatures are much higher--minimum 15°-18° C. (59°-64.4° F.), optimum 31°-37° C. (87.8°-98.6° F.), and maximum 44°-50° C. (111.2°-122° F.). However, there are other crops such as hemp that embrace the whole range of growth temperatures, having the minimum of the cool-season crops and the maximum of the hot-season crops. The cardinal temperatures for growth may vary considerably with the stages of plant development, such as germination, seedling stage, and maturity. Thus seedlings often have lower temperature requirements than plants in later stages.

The optimum temperature that produces the highest growth rate is not necessarily the most favorable for the general welfare of the plant and is often undesirable from an agricultural standpoint. Too-rapid growth may delay or entirely prevent fruiting; it may produce plants that are structurally weak, susceptible to disease or insect attacks, and subject to damage by wind, hail, or other climatic influences. However, wide departures from the optimum will so reduce growth as to make production unprofitable.

Temperature requirements for the same variety of plant vary greatly under different growing conditions. The greater light duration during the summer in more northern latitudes may partly compensate for less heat. Thus, while plants may be classed as requiring much, moderate, or little total heat, a definite number of degree-hours or degree-days does not result in similar development under widely varying conditions.

Unlike warm-blooded animals, plants have no mechanism for controlling temperature independent of environment or for maintaining a uniform temperature throughout the organism. Plant parts have approximately the same temperature as their surroundings.

EFFECTS OF LOW TEMPERATURES

Wherever freezing temperatures occur, plants are in danger of frost injury. There are, however, many habits and modifications by which they are able to survive in regions having temperatures at or below the freezing point. Tender annuals escape freezing by completing their life cycle, from seed to seed, during the period between frosts. Herbaceous perennials die back to the ground but maintain life in underground organs--roots, bulbs, tubers, or rhizomes--which produce new tops when temperatures are favorable. Beneath the soil these organs are either entirely protected from freezing or subjected to much less cold than aerial parts. Coverings of snow or leaves also afford protection from low temperatures, and many low-growing half-hardy plants are able to survive in cold regions because of such covering during periods of extreme cold. Natural protection is frequently supplemented in farming by such practices as mulching.

Cold-hardy plants have the ability to develop cold resistance within their tissues. The degree of resistance varies with different species and varieties. Some herbaceous types, such as cabbage, withstand ice formation in their leaves but are killed by winter temperatures in the colder parts of the country. Hardy wood plants-trees, shrubs, and vines--that endure cold winters without protection develop the greatest degree of cold resistance among higher plants. The exact nature of this remarkable physiological adaptation to cold is still unknown. Within limits, it is possible to secure increased resistance to many species by breeding.

Many correlations have been noted between cold resistance and certain plant characteristics, such as structure and the chemical and physical properties of the cells. None of these factors, however, seems to be common to all cold-hardy plants and none can therefore be regarded as the causal mechanism of cold resistance. The exact nature of cold resistance, as well as the mechanism of injury from freezing, must await a better knowledge of the structure and the physiology of plant protoplasm.

Bark, bud scales, and hairy coatings, often regarded by enthusiastic amateur naturalists as a means of keeping the plant warm, actually have little value in protecting it from cold. At best such coverings only slightly retard the rate of temperature fall, and the plant soon comes to equilibrium with the temperature surrounding it.

In their efforts to extend production into colder regions, farmers and gardeners have persistently carried plants beyond the temperature range to which they are naturally adapted. Consequently, cold injury is common in cultivated plants. Since frost occurs in practically every part of the continental United States, low-temperature injury is an agricultural problem of the entire country, and none of our agricultural areas are entirely free from this hazard.

The nature of freezing damage to crops varies in different regions and with the different kinds of crop plants. In winter-garden sections frosts may kill outright fields of tender crops, such as beans, melons, and tomatoes. Subtropical-fruit districts may experience winter frosts that freeze and ruin green or ripening fruit on the trees. With more severe freezing, the leaves and even the trees are killed.

Over much of the United States late-spring frosts constitute a major hazard of plant production. They may damage or kill young plants of corn, flax, potatoes, cotton, tender garden vegetables, and even seedlings of such comparatively hardy crops as wheat and alfalfa. Plants such as tomatoes, which are normally transplanted into the fields, are usually started in the South or under glass to escape the frost hazard. Deciduous fruits and nuts suffer damage to opening buds, flowers, or young fruit, often to the extent of completely destroying the crop. Flowers, shoots, and leaves of ornamental trees, shrubs, and perennials may be killed or damaged so that their esthetic value is largely lost for the season. Forest trees suffer damage from late spring frosts through destruction of the seed crop, killing back or injury of new growth, and development of frost rings in the wood, which later yields lumber of inferior quality.

Plants overwintering in cold regions are subject to various types and degrees of cold injury. Since not all parts, organs, or tissues are equally cold-resistant, one part may be killed or badly injured while another is undamaged. For this reason, plants apparently hopelessly injured by cold often make a surprising recovery. On the other hand, the effects of winter injury are not always immediately evident. Injured trees or branches may suddenly wither and die after opening their buds, or they may flourish until summer and even flower and fruit before dying. Injury to roots or interference with the conducting system by excretions or outgrowths from cold-injured tissue in the wood may be the cause of such surprising behavior.

Winter injury to herbaceous plants may consist in complete killing, as frequently happens with winter wheat, grasses, alfalfa, clover, strawberries, and many ornamental perennials. Less severe cold may kill buds or injure crowns or roots, as is common with alfalfa and strawberries.

Woody plants may have terminals killed back, and with lower temperatures killing may extend to the snow cover or to the ground. Injury to certain tissues or internal structures of woody stems is common and is generally recognizable by discoloration of the affected part. "Black heart" is an extreme case of such injury prevalent in cold regions, in which pith and often one or more annual rings of wood will be dark-colored. The cambium--the region between the wood and bark where new wood and bark cells are formed--is usually one of the most cold-resistant parts of a dormant stem and often remains uninjured, later laying down new rings of sound wood outside the discolored layers.

Roots are sometimes killed or injured even though the top is unharmed. Hardy fruit or nut varieties budded or grafted on tender rootstocks are likely to suffer from root killing. Winter killing of flower buds is common in many parts of this country, particularly on such crops as peach, cherry, and almond. It also occurs on apple, pear, and many ornamental plants. Local killing of the bark occurs on trees at crotches, at the base of the trunk, and in patches variously located on branches and trunk. Frost cracks and splitting and loosening of bark are mechanical injuries to trees resulting from freezing.

Sunscald is a cold injury occurring on the south and west sides of tree trunks and branches. In cold weather, sunlight falling directly on the bark may warm it several degrees above shaded parts. At sunset the temperature drops suddenly, and killing of the bark results either from the rapid fall in temperature or from freezing of tissues temporarily started into growth by the heating effect of the sun. Such practices as shading or wrapping the trunk or whitewashing to reduce absorption of heat from the winter sun reduce the sunscald type of injury.

Indirect effects of low temperatures on overwintering plants are heaving of soil, resulting in breakage or exposure of roots; the smothering effect of ice sheets; and breaking of trees and shrubs by snow and sleet.

Deleterious effects may result when plants are subjected to low temperatures above freezing. Growth is slowed down, elongation is reduced, and plants become dwarfed and more compact in habit. Definite injuries result from chilling many typically warm-climate plants. Exposure of a day or two at temperatures from slightly above 0° C. (32° F.) to 10° C. (50° F.) may result in yellowing of foliage, dead areas in the leaves, the dropping of leaves, and even the death of the plant.

Not all low-temperature effects are harmful. Many plants, including all of our deciduous fruit trees, have a "rest period," during which no growth takes place, even when all external conditions are favorable for growth. Shoots of woody plants, seeds, bulbs, tubers, and crown buds may exhibit this phenomenon. Some rather drastic treatments, by cold, chemical vapors, or heat, are necessary to break this rest. Cold is the natural means of accomplishing this result. Seed stratification, cold storage of bulbs, and chilling of rhubarb roots and flowering stems of lilac and other woody plants before forcing are commercially applied to break the rest period.

Certain plants seem to require a period of low temperature during germination and early seedling stages in order that later stages of development may be normal. Winter wheat sown in spring does not head; but if the seed is partly germinated and held from 1 to 2 months at temperatures around freezing and then spring-sown, a crop will be produced. This method of shortening the vegetative period and hastening seed production is called vernalization. Many cool-climate plants respond favorably to this treatment.

EFFECTS OF HIGH TEMPERATURES

The effects of high temperatures on plants are difficult to separate from the usually accompanying factors of high light intensity and rapid transpiration. Above the optimum growth temperature the rate of growth drops rapidly, and plants become dwarfed. Temperate Zone plants under tropical conditions tend to make only vegetative growth and to fruit sparingly or not at all. Fruits grown where summer temperatures are excessive for the variety ripen their crop prematurely, and the fruit is poor in flavor, color, and keeping quality. High temperatures cause in certain varieties and strains pollen abnormalities that result in sterility and failure to produce seed or fruit. Heat treatment of floral parts is used as a means of inducing polyploidy (multiplication of the number of chromosomes) in plants. Tissue injuries resulting from high temperatures may kill local areas on leaves, as in tipburn of lettuce and potatoes; scald fruits--such as strawberries and gooseberries; discolor and cause malformation of flowers, as in early blooming chrysanthemums and dahlias; and produce heat cankers on tender plants such as flax, and on the bark of fruit trees. General effects of excessive heat are defoliation, premature dropping of fruits, and, in extreme cases, death of the plant.

WATER SUPPLY AND PLANT DEVELOPMENT

Water supply, from rainfall or irrigation, ranks with temperature as the great determiner of where plant species grow naturally or can be grown agriculturally. Within the great belts of similar temperature conditions, it is more important than any other factor in determining the distribution of plant species and agricultural crops.

Plants may be divided into three great groups on the basis of the moisture condition to which they are adapted: (1) Hydrophytes--water plants or water-loving plants; (2) mesophytes--plants adapted to medium moisture conditions; and (3) xerophytes--plants able to survive under conditions of extreme moisture shortage.

Hydrophytes may grow entirely under water, or, more frequently, with part of the plant structure above water or floating on water. Plants in this group are usually large-celled and have thin cell walls and thin epidermal covering. They often have a relatively poorly developed root system that can survive in the absence of oxygen. They have relatively little protection against water loss. Among important agricultural crops, rice most nearly approaches the typical hydrophyte. Such crops can be grown only where water, from either rainfall or irrigation, is extremely abundant.

The mesophytes, requiring a medium amount of water, include the greater proportion of our agricultural crops. Such plants need moderate soil moisture and also good aeration around their roots, as the root system must have oxygen for development. They have moderately large root systems in proportion to the tops. Their structures are composed of medium-sized cells with surface covering well developed to prevent excessive water loss. Stomata, or pores, in the leaves usually close under conditions of incipient leaf wilting. Thus the plants are moderately well protected against water loss.

The third class, xerophytes, includes plants highly resistant to drought conditions. Usually their structure is such that water loss is reduced to a minimum--leaves are small, all epidermal coverings are thick and heavily covered with waxy material (cutinized), stomata are small and are frequently set in pits instead of on the surface of the leaves, and cells are small and thick-walled. Much of the true xerophytic vegetation has large root systems. Such plants usually grow slowly when moisture is available but are highly resistant to water loss and can survive long periods of drying. Since they are generally slow growing, they are not of great importance agriculturally. However, the native xerophytic vegetation of arid sections provides some feed for livestock and is important in reducing soil erosion.

In arid regions, in addition to xerophytic plants, there is usually an additional flora of quickly maturing plants that grow from seed and produce flowers and fruits during short seasons when rainfall occurs. The seeds then remain in the ground until moisture and temperature conditions are again favorable for growth. Such plants are mesophytic in type and develop only when moisture is ample.

A plant properly classed as a mesophyte tends to assume some of the characteristics of xerophytes when grown with a shortage of moisture and some of those of hydrophytes under conditions of abundant moisture. Thus the individual plant grown with abundant moisture will generally have larger leaves, larger cells, thinner cell walls, and less highly developed surface coverings than plants of the same variety or species grown under conditions of deficient water.

THE ROLE OF WATER IN PLANTS

Most growing plants contain much more water than all other materials combined. C. R. Barnes has suggested that it is as proper to term the plant a water structure as to call a house composed mainly of brick a brick building. Certain it is that all essential processes of plant growth and development occur in water. The mineral elements from the soil that are usable by the plant must be dissolved in the soil solution before they can be taken into the root. They are carried to all parts of the growing plant and are built into essential plant materials while in a dissolved state. The carbon dioxide from the air may enter the leaf as a gas but is dissolved in water in the leaf before it is combined with a part of the water to form simple sugars--the base material from which the plant body is mainly built. Actively growing plant parts are generally 75 to 90 percent water. Structural parts of plants, such as woody stems no longer actively growing, may have much less water than growing tissues.

The actual amount of water in the plant at any one time, however, is only an infinitesimal part of what passes through it during its development. The processes of photosynthesis, by which carbon dioxide

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and water are combined--in the presence of chlorophyll and with energy derived from light--to form sugars, require that carbon dioxide from the air enter the plant. This occurs mainly in the leaves. The leaf surface is not solid but contains great numbers of stomata, or pores, through which the carbon dioxide enters. The same structure that permits the one gas to enter the leaf, however, permits another gas--water vapor--to be lost from it. Since carbon dioxide is present in the air only in trace quantities (3 to 4 parts in 10,000 parts of air) and water vapor is near saturation in the air spaces within the leaf (at 80° F. saturated air would contain about 186 parts of water vapor in 10,000 parts of air), the total amount of water vapor lost is many times the carbon dioxide intake. Actually, because of wind and other factors, the loss of water in proportion to carbon dioxide intake may be even greater than the relative concentrations of the two gases. Also, not all of the carbon dioxide that enters the leaf is synthesized into carbohydrates.

While the air spaces inside the leaf are normally at or near saturation in plants not in a wilted condition, the moisture in the air surrounding the leaf may vary from full saturation to as low as 10-percent saturation. The drier and hotter the air surrounding the plant in general the more rapid the water loss in proportion to carbon dioxide intake. Thus in the drier, hotter areas the total water required to grow a plant to a given size will be greater than in areas where the air contains greater average quantities of moisture. Also water loss is more rapid when there is much wind than on a still day with the same temperature and humidity.

Water enters the plant primarily through the root system, which in most plants, at least those growing in a medium to dry environment, is usually more extensive than is generally realized. Weaver and Clements, in Plant Ecology (one of the sources for this manual) state that corn in open soil will root almost as deeply as the height of the stalk; that the roots of a single lima bean or cabbage plant may ramify through 200 cubic feet of soil; and that many grasses and legumes have roots 16 feet deep in the soil. In open soils planted to such crops it may be impossible to find even a cubic inch of soil in the upper 2 or 3 feet that is not penetrated by roots.

The amount of moisture that the soil will hold against the downward force of gravity is termed the "field capacity" and varies in general with the fineness of the particles making up the soil. The moisture is held in the soil as films of water around the soil particles, and the total amount held is roughly proportional to the total amount of these surfaces. As the young roots penetrate the soil they are in contact with these moisture films, and the water enters them largely as a result of the physical process called osmosis.

Not all the water in the soil, however, can be absorbed by the plant. If the films of water surrounding each soil particle become thin, the rate of capillary flow becomes less until the root is no longer able to absorb water. If this condition is reached in much of the root zone the plant wilts, because water is lost more rapidly from the top than it is supplied by the roots. The point at which the roots are no longer able to absorb appreciable moisture from the soil is termed the "wilting percentage," the moisture below that point being unavailable for plant use. The available moisture capacity of the soil is the amount of water available for plant use that it will store, or the amount between field capacity and wilting percentage. In general, the moisture content at the wilting percentage is a little less than half that of field capacity, though this varies in different soils.

The amount of available water that the soil will hold varies greatly with the soil texture and structure. Thus coarse, sandy soils may not hold more than half an inch of available water per foot of depth. Moderate-textured loam soils will usually hold 1-1/2 to 2 inches of available water per foot of depth, while some clay soils will hold as much as 3 inches. Thus the light, coarse-textured soils that hold little available water are known as droughty and are of value agriculturally only under conditions of very frequent and regular rainfall or where abundant irrigation water is available. On the other hand, soils of high available water-holding capacity frequently will store enough water to mature satisfactory crops even though no rainfall occurs during the period of crop growth.

The most critical period of water shortage in a plant is when it is making its most rapid growth, or when cell division is occurring most rapidly. In crops grown for their seed, the most critical period is likely to be the time of fertilization of the flowers, since lack of water then is likely to result in failure to form seed. In plants grown primarily for their leaves and stems, such as the forage crops, water shortage is likely to reduce production more during the earlier stages of development than during the later stages before harvest. With tree fruits such as cherries and peaches, the period of rapid growth just before maturity is the most serious in reducing production.

In perennial plants, which form their flower buds during the season preceding that in which the buds flower and fruit, moderate water shortage tends to result in increased fruit-bud formation. Thus seasons of moderate water shortage usually are followed by abundant bloom the following spring in many fruit and forest trees.

Many of the basic farm practices, particularly in regions of limited rainfall, are based on conservation of water. Summer fallowing is primarily to secure 2 years' rainfall for one crop. Contouring and mulching are based in part on securing penetration into the soil of all water that falls. Clean tillage of cultivated crops during the growing season removes the competition of weeds for water. Irrigation is supplying water to plants that could not develop properly without it. Finally, much has been accomplished and more is possible in breeding varieties of agricultural plants that will thrive under conditions of limited water supply.

SOILS AND THEIR FLORA AND FAUNA

There are many different sorts of soils and many different conditions of soils. The first cannot be altered, the second can, and it is the farmers' object to maintain it as the most acceptable medium for plant growth.

In order that a plant's roots may thrive they need moisture, food, air, warmth and anchorage. An ideal soil, then, will hold and conduct moisture, contain an abundance of available food, permeated with an extensive network of cracks and channels, yet compact to aid water movement and anchorage. We have already studied the plant's food, but the remaining items are mainly bound up with soil structure.

Natural undisturbed soils consist of a friable surface layer filled with a mat of roots perhaps 2 or 3 in. thick and containing a quantity of decaying plant remains. Underneath there is another layer of crumbly earth of a dark colour about 6 in. thick, but in which the crumbs are all fitted compactly together like a jig-saw, being separated merely by fine cracks. Fine roots penetrate between these cracks and expand, squeezing the plastic soil crumbs into different shapes and, at the same time, closing up some cracks and opening others so that a constant supply of fresh feeding surfaces is available to the plant.

In addition to these cracks there are the larger perforations made chiefly by earth-worms, more especially on well-drained but moisture-retentive soils. These form the main conduits for the access of air and for the drainage of surplus moisture. Worms are constantly feeding on soil in one place and dumping it, in a more finely divided and mixed condition, in another.

In some parts of the world there are no earth-worms to provide drainage. Such places have long dry periods so that waterlogging is remote in any case. The need for these burrows, therefore, is not great, unless long wet periods intervene, as in the Tropics, where ants often serve the same purpose. In rather dry temperate climates, where microbial activity is low, a fibrous type of organic matter accumulates at the surface and its slow decay gives a finely granulated but fairly well aerated soil--the prairie soil.

Going deeper, the cracks become fewer but larger, so that the individual soil crumbs become soil blocks with more or less vertical divisions formed by the alternate drying and shrinking, and wetting and expansion, of the body of the soil. Down these cracks the plant tap roots go in their search for moisture and often for minerals also. The worm-holes, too, become fewer but larger, only the large worms are found below 9 in., the great majority of worms living mainly in the top 6 in. Disused worm-holes again become easy passages for roots.

These larger channels, in well-drained loamy soils, often go down 6 ft., and many of our crops go to this depth, especially root crops and others possessing tap roots. Roots of lucerne in some dry American soils have been found at 30 ft. There is seldom any need for roots to travel such distances for moisture in this country except on shallow soils overlying fissured rocks.

Plants use a lot of water while building up their substance, though only about ½ to 1 per cent of the water taken up is actually built into the sugars and other materials that make up the plant body or used in plant processes. The remainder is evaporated by the plant through its leaves and stems during transportation, drawing up a good deal of nutrients from the root at the same time.

It has been found that a plant needs at least 20 gallons of water to form 1 lb. of dry weight, and up to 80 gallons in dry climates--in the latter case simply to keep the plant tissues from wilting under the intense evaporation.

The water content of average soils on a rough basis is the equivalent of about 1 in. of rain for every foot of sandy soil and 2 in. for every foot of clay soil, with loam soils taking an intermediate position.

There are a variety of soils, more or less extreme cases, with high proportions of sand, clay or silt. A loamy soil containing about 40 per cent of sand, 40 per cent of silt and 20 per cent of clay may be taken as the standard, in which the sand and silt particles are bound together by clay to form the small soil crumbs. Only clay, of the mineral constituents, has this binding property--a sort of gelatinous stickiness which is only too obvious to those afflicted with clay soil. Silt, which is a grade of soil particles intermediate between clay and sand does not possess this stickiness. For that reason, it does not hold itself together in crumbs but easily breaks down to dust or mud with cultivation, and in wet weather effectively seals off soil pores with the possibility of suffocation of plant roots.

Sand particles, being coarser still, though having no binding properties again, will nevertheless allow air to penetrate into the soil.

There is sometimes a danger, however, that if it contains a proportion of silt this will wash down and accumulate at a lower layer, forming a kind of pan.

All these extreme types have one thing in common. They are all improved, cumulatively, by decaying organic matter. They are improved in two ways. By an improvement in structure and an improvement in water-holding capacity. This is brought about by the presence of large numbers of bacteria and fungi and their remains, which are of a mucilaginous or gummy nature. This helps the silt and sand particles to combine into crumbs. Fungal hyphae have a similar effect. It also permits the cracks in clay soils to remain open; this mucilage being of a much less sticky material than the clay itself. It creates lines of weakness between the clay crumbs and blocks. Unfortunately, these effects only hold as long as the micro-organisms are supplied with organic matter. A good soil with a good structure is one that will work to a tilth over a wide range of moisture conditions without the individual crumbs losing their entity under rain.

Water-holding capacity is improved in two ways: by the presence of these mucilaginous materials and, in the case of clay and silt soils, by the formation of fine cracks which hold thin films of moisture. Though the relative quantity of these colloidal materials is not great they can hold up to ten times their bulk of water. An annual dressing of 14 tons of dung per acre, over many years, has been shown to increase the water content of the top 9 in. of the soil by about a third, that is, from 2 in. to about 2 3/4 in. And consequently reducing the loss by drainage, as the following figures from Rothamsted show.

Average number of days on which the field drains were running:

Dunged land	0.7 days	during the same period
Undunged land	19.5 days	

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PROVIDING THE FOOD

It remains now to discuss the mechanisms by which these crops are produced.

In order to produce good crops, plants need a steady and liberal release of nitrogenous compounds, potash, and phosphates, and all other necessary adjuncts to the plant's health.

All this is provided, under natural conditions, by one means, through the activity of soil organisms. These in turn require food, mainly as a source of energy. There is a great distinction here--the plant provides its own energy from light and often some to spare for symbiotic organisms. The micro-organism has to find its energy requirements direct from the soil particles.

The need of soil organisms for nitrogenous materials in the shape of dung, and so forth, has been stressed to the point of imbalance. Certainly they need nitrogen (and minerals), but they need fifty times as much energy-providing food. We give them ample roast beef but forget their bread and butter.

This energy supply consists of carbohydrates which are in turn plant remains, plant skeletons. It may be divided into various fractions varying slightly in their chemical constitution and considerably in their rate of availability as food to the micro-organisms. The most easily used fractions are sugar and starch; next come the hemi-celluloses and celluloses used for plant skeletons in herbaceous plants; and finally the lignins, found in trees and other hard, woody stems, sometimes to the extent of 30-40 per cent of the total carbohydrate. Lignin, it seems, can only be decomposed by fungi, whereas the first two groups can be utilized by bacteria as well. These materials are converted to carbon dioxide with the evolution of energy; indeed, the quantity of carbon dioxide liberated is a direct indication of the biological activity of the soil and consequently of its current fertility. (But not necessarily of its total or potential fertility, except under natural conditions, as biological activity can be stimulated by cultivations, addition of nitrogen and other nutrients, etc.)

A notable point of the natural cycle of plant growth and decay is its economy of nutrients. This is obvious enough in tropical climates where fallen leaves and branches decay rapidly and the plant foods they contain are equally rapidly assimilated by the surrounding growth. In most temperate climates, where most of the rain falls in autumn, the mildness and warmth of the soil at this time, coupled with the fact that plants can no longer grow very much on account of the shortage of light, decay and nitrification release a good deal of nitrogen into the soil which is in danger of being washed away. In fact, however, it is at this time of year that the fungi come into their own feeding on the freshly-fallen leaves and stems, or dead grasses, and incorporating this free nitrogen into their protoplasm where it is held until the following year. Then, with a diminution in food supply and alternate droughts and rains of spring and summer, much of this fungal material dies and the nutrient is absorbed by the plants again. Worms also are active in autumn and assist by dragging plant remains into the soil or feeding on them, thus rendering them more suitable for fungal use. It would seem wise, then, to imitate Nature by applying undecomposed residues to the soil in autumn.

Bacteria, of course, are active more or less throughout the year, but their activities, which are greatest in autumn, would be rather in a secondary capacity after the plant remains had been incorporated with the soil by worms and fungi.

A soil well supplied with organic matter and in its natural uncultivated condition does not lose nitrogen readily by leaching with heavy rain for another reason. It appears that the water percolates rapidly down cracks and worm-holes to the subsoil, leaving the bulk of the plant food in the body of the soil granules or crumbs.

The ideal situation for this organic matter, it seems, is as near the surface as possible. Here again evolution can provide us with a clue. Plant and animal remains, with the exception of plant roots and soil animals, are deposited on the surface and dragged under bit by bit by worms and to a limited extent by other animals. Here it is either mixed up with finely-divided soil particles by the worm and excreted in an ideal form for further breakdown by bacteria and fungi, or it is acted on by these agents directly at the soil surface where the lower layers of litter are moist and shaded. It will be noted that the decay is invariably aerobic, encouraging nitrogen-fixing and nitrifying bacteria, and it is also adjusted to the plants' needs, giving an increased supply of plant foods in warm and damp weather when plants are growing quickly, and decreasing during cold or dry weather when plant foods cannot be used. A very different set of events takes place when organic matter is ploughed in, especially under modern conditions of deep ploughing and artificial manuring.

The plant and animal residues are put into a permanently damp atmosphere at the bottom of the furrow with a varying degree of aeration according to the depth of ploughing and type of soil. Providing the soil is not cold, e.g. winter time, decomposition is immediate and rapid, resulting in a large microbial and fungal population. Providing the residues contain 1½ per cent or more of nitrogen, there will be sufficient of this element to support the plant as well as the micro-organisms. But also, if plenty of nitrogen is present, the carbohydrates in the organic matter will be used up quickly, giving a further and rapid release of nitrogen on the death of micro-organisms by starvation. The crop may be able to take up quickly all this nitrogen, but generally, as will be shown in a moment, excess nitrogen in the soil is liable to severe losses. This rapid evolution of nitrogen is followed subsequently by a comparative shortage and the plant may starve if not already mature, even though large amounts were added in the first place. When quickly available nitrogenous fertilizers or dung are used these effects occur even more rapidly.

There is another reason why the organic matter should be left on the surface. The carbohydrate of plant remains is converted to humus chiefly by fungi and to a comparatively small extent by bacteria. When these remains are turned under by the plough much carbon dioxide is evolved by bacterial action, which in turn suppresses the fungi, so that carbon dioxide rather than humus is formed.

There are two, more serious, disadvantages to the use of nitrogenous manures not generally known--there appears to be no discrimination here between the inorganic forms and the organic forms of concentrated nitrogenous manure--such as dried blood, and hoof and horn. These difficulties again are associated only with present methods of agriculture.

It is obvious that a superabundance of a particular kind of food will result in a rapid increase in the particular kind of organism that enjoys that food: take, for example, the growth of yeast in a sugary solution or the prolificacy of rabbits where there is plenty of winter grass. So it is when we add nitrogenous manures to the soil. These are added as, or are soon coverted into, nitrates. Certain organisms can obtain both body-building materials and oxygen for their energy by breaking down nitrates--the denitrifying organisms. These can work without or with air, but more commonly without--so the process is more rapid when the manures are turned under by the plough.

They destroy the nitrates and convert them to atmospheric nitrogen--they are then lost to the plant. Indeed, the fact that these organisms can work under any conditions seems to indicate that nitrates have a short life in the soil. In warm weather this destruction of nitrogenous fertilizer takes two to three weeks under suitably moist conditions, that is why in market gardening top dressings have to be applied at about this interval.

Rothamsted shows how an application of 14 tons per acre of dung (which contains a particularly high proportion of denitrifying organisms) to the acre loses 70 per cent of its nitrogen, while 4 cwt. of sulphate of ammonia annually lost 60 per cent. The higher the application the greater is the proportionate loss.

LOSS OF NITROGEN FROM A CULTIVATED SOIL

Broadbalk, Rothamsted--49 years, 1865-1914
As lb. per acre in top 9 in.

	Farmyard Manure Annually at 14 tons per acre	No Manure	Complete Artificials including 86 lb. N. as Sulphate of Ammonia Annually
N. in soil in 1865--lb. per acre	4,850	2,960	3,390
per cent	0·196	0·114	0·123
N. in soil in 1914--lb. per acre	5,590	2,570	3,210
per cent	0·236	0·092	0·120
Total change in 49 years--lb.	+740	-390	-180
N. added in manure, seed and rain--per ann.	208	7	93
N. removed in crop--per ann.	50	17	46
N. retained or lost--per ann.	+15	-8	-4
N. unaccounted for--per ann.	143	(gain 2)	51

This loss is equivalent to three crops of 30 bushels of wheat annually. Some of the loss may be due to leaching, but as this loss also occurs in dry climates it seems unlikely to account for much of it. It has also been suggested that the crop plant itself breaks down the nitrates--but there does not seem to be any need to postulate such a view.

In my own experience, plots of land receiving large quantities of dung and artificals for three years in succession gave no support to cabbage seed sown subsequently. While blackcurrant and other crops needing much nitrogen gave very satisfactory crops with a mere mulch of straw and no manure.

The best we can manage, when using concentrated nitrogenous nourishment for the plant, is to provide a rapidly fluctuating food supply, very dependent on rain for its solution and consequent assimilation, and with a risk of scorching the roots or depriving them of water in dry weather. It is for this reason that these crop yields vary so widely from year to year.

The other wasteful effect of nitrogenous manures not generally known is that it stimulates bacteria, including the nitrifying and denitrifying types, to search around for any possible source of carbonaceous matter for energy, and they will decompose the forms of humus (peaty material) which are normally fairly resistant to breakdown and have a great influence on soil structure. It is this effect that has, above all others, given artificial manures a bad name in many quarters—but it is not confined to artificial manures. We have the curious anomaly whereby the ploughing-in of a succulent green crop leaves the soil with rather less organic matter than before, owing to the fact that it contains much nitrogen (page 45). Even dung almost entirely decomposes itself, as can be seen in the case of a heap of manure left for twelve months on a paved yard. An annual application of 14 tons per acre is just sufficient to keep the organic matter at an economic level and, as already shown, the losses of nitrogen are enormous. If only for this reason, it is much more economic to compost dung either with fibrous plant residues or by spreading on grassland (sheet composting) so as to bring the proportion of nitrogen to about 1½ per cent of the carbohydrate. Again, this effect is aggravated by our agricultural customs.

When ploughing-in a young green crop of, say, mustard or ryegrass, a rapid decomposition and release of plant foods takes place which unfortunately is completed in 1-2 months and may be followed by starvation of the plant. So the plant has to be kept going with top dressings, hoping for rain to render them effective. Or it is given a heavy dressing of artificials, in the first place, in the hope that it will see the crop through—with a further loss of organic matter.

The above wastages take place when the dung or green crop is ploughed in immediately before spring sowing. It seems more usual, however, to plough in these materials in autumn. The losses of humus and nitrogenous plant foods are much more severe--the period of maximum nitrification coincides with the autumn rains and much of the soluble nutrient is washed away. We are faced again with the necessity of a spring top dressing.

Supposing, now, the crop of green manure is allowed to become mature and woody, and ploughed in. The proportion of nitrogen is much less than 1½ per cent, probably more like ½ per cent. All the available nitrogen in the soil is seized by the microbes to build up their bodies for the attack on the celluloses and their conversion to humus. The crop goes short. Another top dressing of fertilizers or basal application ploughed in, to compensate. There is, as before, a gradual decay and consequent release of plant food from this woody material. Unfortunately, the crop may not get the benefit from it until late in the season, or perhaps not at all. The decomposition may be completed by the onset of autumn and the wet weather will soon get rid of the hoped-for benefit. However, under the present system this is probably the best that can be achieved.

If, however, this woody material had been left on or near the surface, micro-organisms would not have been able to attack it in entirety, so absorbing all the soil nitrogen, as it would not have been in a permanently moist condition. It would also have provided the surface living nitrogen-fixing organisms with food to fix some nitrogen for the crop. Thus by ploughing in organic matter, not only do we not gain any nitrogen but we also lose some of what we had.

The losses of organic matter from the soil in spite of ploughing in green-manure crops are well demonstrated by the following table. In these experiments the green manure was sown in maize in the third week of August, and ploughed in during the first week of May before sowing the maize, over a period of five years.

It will be noted that, generally speaking, the loss of humus is least where about a ton of dry matter, with a nitrogen content of between 1·2 and 1·7 is added. Crimson and alsike clovers, giving a large amount of dry matter but of a soft succulent nature high in nitrogen, cause the greatest loss. Winter vetch, on the other hand, forms a large weight of relatively mature tissue on account of the much better start in life provided by the relatively large seed reserve. Crop yields, not surprisingly, correspond with the amount of nitrogen added, but would decline over a long period where the soil organic matter was not maintained.

	Dry Weight of Plants lb. per acre annually	Nitrogen in Plants lb. per acre annually	Nitrogen Content of Plants per cent	Yields of Maize per cent	Loss of Humus as Carbon over 5 years, as per cent of Soil	Total Dry Matter Added over 5 years tons
Weeds only	1,263	18·9	1·50	100·0	0·08	3·15
Winter Vetch	3,812	133·0	3·49	127·8	0·02	9·53
Crimson Clover	3,048	92·4	3·03	115·6	0·10	7·62
Red Clover	1,786	50·4	2·82	114·7	0·05	4·46
Sweet Clover	1,436	39·5	2·75	113·7	0·07	3·57
Alsike Clover	1,983	53·1	2·68	104·4	0·11	4·96
Winter Wheat	2,089	34·1	1·63	99·7	0·10	5·22
Winter Rye	2,463	31·8	1·29	95·3	0·10	6·15

It will be seen that the accustomed practice of repeatedly ploughing in young green crops and mowing grass orchards to 'build up fertility' is, in fact, doing the reverse--though in doing so it is stimulating the activity of micro-organisms in the soil, which will have some beneficial effects at the time. We must keep clear the distinction of 'building up fertility', i.e. nitrogenous humus compounds, which also preserve soil structure, and keeping up a high level of bacterial activity for some specific purpose, e.g. release of soil minerals. The two processes are largely antagonistic. One cannot save and spend until one has accumulated some capital.

It seems, then, that the more nitrogen used the faster the organic matter is used up. The less organic matter, the poorer the soil aeration; the poorer the aeration, the deeper one must plough and cultivate. The deeper one ploughs, the more nitrogen must be used in an attempt to balance the activity of the denitrifying organisms.

SOIL CLASSIFICATION AND SURVEYS

Soil maps are a basic tool for selecting a system of soil management. The maps show the kinds of soil in a field and farm--essential knowledge for selecting from the various available soil-management practices the combination of practices that is best suited to the soil and to the resources, skills, and desires of the farmer and rancher.

If they know the effect of a given practice on a field, whose kind of soil also is known, they can foresee the effect of that practice on other fields with the same kind of soil. Just as they can predict the behavior of a particular variety of hybrid corn, so can they predict the response to management of a particular soil.

Soils are classified and named, just as plants and animals are. Plants are identified by such characteristics as the structure of the flower and the form of the leaf. Soils are identified by such characteristics as the kinds and numbers of horizons, or layers, that have developed in them. The texture (the relative amounts of stones, gravel, sand, silt, and clay), the kinds of minerals present and their amounts, and the presence of salts and alkali help distinguish the horizons.

Most of the characteristics that identify soils can be determined in the field. A few can be determined only in the laboratory, but even without laboratory tests you often can get an accurate knowledge of them from standard works on soils and geology. For example, you can estimate the amount of sand in a soil from its feel when you rub it between your fingers, but for an accurate knowledge you would have to depend on laboratory analyses.

The type is the smallest unit in the natural classification of soils. One or a few types constitute a soil series. These are the common classification units seen on soil maps and survey reports.

A soil series is a group of soils that have horizons that are essentially the same in the properties used to identify soils, with the exception of the texture of the surface soil and the kinds of layers that lie below what is considered the true soil.

The names of soil series are taken from the towns or localities near the place where the soils were first defined.

The soil type, a subdivision of the soil series, is based on the texture of the surface soil. Stones, gravel, sand, silt, and clay have been defined as having the following diameters: Gravel, between 0.08 inch and 3 inches; sand, between 0.08 and 0.002 inch; silt, between 0.002 and 0.00008 inch; and clay, less than 0.00008 inch.

The full name of soil type includes the name of the soil series and the textural class of the surface soil equivalent to the plow layer--that is, the upper 6 or 7 inches. Thus, if the surface of an area of the Fayette series is a silt loam, the name of the soil type is "Fayette silt loam."

The soil phase is not a part of the natural classification. It can be a sub-division of the soil type, series, or one of the higher units in the classification.

Phases shown on soil maps commonly are subdivisions of soil types and are based on characteristics of the soil significant to its use for agriculture.

Phases shown on large-scale soil maps generally have reflected differences in slope, degree of erosion, and stoniness, but other bases for defining phases include drainage and flood protection, climate, and the presence of contrasting layers below the soil. (A comparable subdivision in the classification of animals might be classes according to their age, such as old animals, old cows, or old Holstein cows.)

The legends that accompany soil maps generally include such names for the units on the map, as "Sharpsburg silty clay loam, eroded rolling phase," or "Fayette silt loam, 8-14 percent slopes, eroded." Those names identify the soil series, the soil type, and the phase. They represent names of the most specific kinds of soil, comparable to the name of a practical subdivision of a variety of a plant, such as old Jonathan apple trees.

The word "Fayette" in the second soil name we mentioned is the name of the soil series. This name, plus the words "silt loam," identify the soil type, and the phase is identified by the words, "8-14 percent slopes, eroded." In this name, the word "phase" is not used but is understood.

Higher units in the classification system include families, great soil groups, suborders, and orders. They are seldom used on any but small-scale soil maps.

Soil series, types, and phases do not occur at random in the landscape. They have an orderly pattern of occurrence that is related to the land form; the parent material from which the soil was formed; and the influence of the plants that grew on the soils, the animals that lived on them, and the way men have used them.

On a given farm, the different kinds of soil commonly have a repeating pattern, which is associated with the slope.

The relationships between the soils and landscapes vary in details in different parts of the country, but the relationships generally exist. Anyone who is familiar with the soils can visualize the landscape from a soil map; or, if he sees the landscape, he can predict where the boundaries are.

A soil survey includes finding out which properties of soils are important, organizing the knowledge about the relations of soil properties and soil use, classifying soils into defined and described units, locating and plotting the boundaries of the units on maps, and preparing and publishing the maps and reports.

The soil survey report consists of a map that shows the distribution of soils in the area, descriptions of the soils, some suggestions as to their use and management, and general information about the area.

Reports usually are prepared on the soils of one country, although a single report may cover several small countries or only parts of countries.

Soil surveys are made cooperatively by the Soil Conservation Service of the Department of Agriculture, the agricultural experiment stations, and other State and Federal agencies. Plans for the work in any area are developed jointly, and the reports are reviewed jointly before publication.

Soil maps have many uses, but generally they are made for one main purpose--to identify the soil as a basis for applying the results of research and experience to individual fields or parts of fields. Results from an experiment on a given soil can be applied directly to other areas of the same kind of soil with confidence. Two areas of the same kind of soil are no more identical than two oak trees, but they are so similar that (with comparable past management) they should respond to the same practices in a similar manner.

But many thousands of kinds of soil exist in the United States. Research can be conducted on only a few of them. The application of the research results must usually be based on the relationships of the properties of the soil on which the experiment was conducted to the properties of the soils shown on the maps. This can be done best by the soil classification system.

The significant properties that can be known from the soil maps include physical properties, such as the amount of moisture that the soil will hold for plants, the rate at which air and water move through the soil, and the kinds and amounts of clays, all of which are important in drainage, irrigation, erosion control, maintenance of good tilth, and the choice of crops.

Some important chemical properties can be known from the soil maps. The ability of a soil to convert phosphate fertilizer to forms unavailable to plants is an example. Generally speaking, however, the ability of a soil to supply nutrients needed by plants cannot be known with precision from the soil map alone, for the supplies of the nutrients are changed when a farmer applies fertilizers.

Soil tests on individual fields are becoming more and more important. Considered in relation to the kind of soil, they form the most reliable background for recommending the application of fertilizers.

The soil map shows the distribution of specific kinds of soil and identifies them through the map legend. The legend is a list of the symbols used to identify the kinds of soil on the map.

The most common soil units shown on maps are the phases of soil types, but other kinds of units may be shown.

The soil bodies, areas occupied by the individual soil units, generally range from a few acres to a few hundred acres. Often within one soil body are small areas of other soils--series, types, or phases. If the included soils are similar in nature, they are generally not identified unless they represent more than 10 or 15 percent of the soil body in which they are included. If the properties of the included soils differ markedly from those of the rest of the soil body, they usually are indicated by special symbols.

But occasionally the individual parts of a unit are so small and so mixed with other units that they cannot be shown. Then the legend will indicate the area occupied by the intricate mixture as a soil complex if all of the included units are present in nearly every area.

A complex may consist of two or more phases of a soil type, but commonly it consists of two or more series. The names of complexes may carry a hyphen between the names of two soil types or phases, as "Barnes-Buse loams." If several series or types are included in the complex, the names of one or two of the most important series or types will be followed by the word "complex," for example, "Clarinda-Lagonda complex."

Two other kinds of units are common on soil maps--the undifferentiated group and the miscellaneous land type.

Two or more recognized kinds of soil that are not regularly associated in the landscape may be combined if their separation is costly and the differences between them are not significant for the objective of the soil survey. This kind of undifferentiated group is shown in the legend with the names of the individual units connected by a conjunction--for example, "Downs or Fayette silt loams."

The miscellaneous land types are used for land that has little or no natural soil. The map units then are given descriptive names, such as "steep, stony land," "gullied land," and "mixed alluvial land."

The relationships between the units that appear on the maps and legends and the use and management alternatives are explained in the text that accompanies the soil survey report.

HOW TO DETERMINE NUTRIENT NEEDS

You can tell whether soil needs fertilizers by the health and productiveness of the plants that grow on it.

Plants in poor health may be stunted or--when nutrients are critically low--show signs of sickness on leaves, stems, or fruits. In some plants, however, the need for more or different nutrients is less easily seen. Often they may not appear stunted or show deficiency symptoms, but they will respond to the addition of nutrients to the soil. This hidden hunger will become more common as farmers increase their yields.

Three steps are necessary to determine the nutrient needs of soil:

The problem must be diagnosed.

The degree of deficiency must be determined.

The amount of fertilizer needed for the desired yield must be found.

Plants and soil conditions must be examined in detail in the field. There is no way of getting around that. This diagnosis can then be checked by simple fertilizer tests in the field or greenhouse, by quick tests of plant tissues, and by analysis of soils and plants.

Often you can easily see that a crop is not making proper growth. Sometimes plants exhibit general or specific symptoms of poor nutrition. Too little sulfur and nitrogen, for example, produce a general chlorosis--a yellow or pale-green color over the entire plant. Some deficiencies, like that of iron, show up mostly in the younger tissues; the young leaf blades are white or pale yellow but the veins may be normal.

Although symptoms are a useful guide to the need for nutrients, one has to be careful in interpreting them, particularly when two or more deficiencies exist at the same time. Climate also may affect the expression of symptoms. Therefore the diagnosis should be confirmed by chemical tests of the plant tissues or by applying the nutrient to the soil or the foliage and seeing how the plant responds.

Of particular importance in diagnosis is the influence of the soil profile. Poor drainage may induce symptoms of deficiency. An example is so-called lime-induced chlorosis, or iron deficiency, which is common on susceptible crops or poorly drained sites in the West. Plants in fields where surface soil has been removed by erosion or in preparation for irrigation often are deficient in nitrogen, phosphorus, iron, potassium, or zinc, especially if the sub-soil contains lime. Overliming can induce some deficiencies on acid soils. Deficiencies of one or more elements frequently occur where sand or gravel underlies shallow soil.

It is important but not always easy to exclude other possible causes of poor growth or symptoms that look like mineral deficiencies. Some insects suck juices from plants and so reduce growth. The toxins of some insects deform plants and produce symptoms like those of mineral deficiency. Nematodes may retard development of roots.

Some plant diseases, particularly the virus diseases, produce leaf patterns that can be confused with symptoms of mineral deficiency. So do various organisms that produce dead areas in leaves. Root rot can reduce the ability of a plant to forage for nutrients.

Excess salts in the soil reduce the entry of water into plants and restrict their growth without producing specific symptoms of deficiency. This problem is common in western irrigated areas and may become so in the Eastern States. Accumulation of sodium on the clay of soils leads to an alkali condition that often is linked with poor growth or no growth of crops and the presence of deficiency symptoms of iron and sometimes zinc.

The damage done by drought may be mistaken for nitrogen deficiency in grains, corn, sorghum, and grasses.

Frost damage may also produce symptoms that may appear to be deficiencies of nutrients.

Applying fertilizers too close to the seed at planting or side-dressing fertilizers at too high rates or too close to the plants may produce injuries that reduce growth or kill plant tissues.

Improper cultivation may result in deficiency symptoms. Lightning may sear small areas in a field.

After you have made a field diagnosis, you can confirm it by pot experiments in a greenhouse or strip tests in the field. These tests are made by adding (singly or in various combinations) the fertilizer elements suspected of being deficient and observing the plant growth that results.

The next step is to determine the extent of the deficiency.

One way to do that is to make an experiment in the field itself. The deficiency is estimated by adding nutrients and determining what effect the additions have on the plants. The fertilizer containing the nutrient is added to the soil or sprayed on the plants at various rates of application--more than one nutrient may be deficient, and several rates of each nutrient may be added in combination with different rates of the others.

Several kinds of information may be had from these experiments. The simplest is the response curve of yield in relation to the amount of nutrient supplied. It gives information about the supplying power of the unfertilized soil in terms of bushels or tons of produce. If the increase in yield is great, the experiment shows that the soil has too little of the nutrient in question. The shape of the response curve also shows how much nutrient is needed to produce the desired yield level under the existing set of conditions.

pH, SOIL ACIDITY, AND PLANT GROWTH

When crop plants do not grow well, one of the first questions the soil scientist usually asks is, "What is the pH of the soil?" or, "Is the soil acid, neutral, or alkaline?"

The reason for these questions lies in the fact that the pH, or degree of acidity of the soil, often is a symptom of some disorder in the chemical condition of the soil as it relates to plant nutrition.

A measurement of soil acidity or alkalinity is like a doctor's measurement of a patient's temperature. It reveals that something may be wrong but it does not tell the exact nature of the trouble.

The acidity or alkalinity of every water solution or mixture of soil and water is determined by its content of hydrogen ions and hydroxyl ions. Water molecules break up, or in chemical language, ionize, into two parts--hydrogen ions and hydroxyl ions. When there are more hydrogen ions than hydroxyl ions, the solution is said to be acid. If there are more hydroxyl ions than hydrogen ions, the solution is alkaline (or basic). Solutions with equal numbers of hydrogen and hydroxyl ions are called neutral.

Only a very small percentage of the water molecules present are broken up into hydrogen and hydroxyl ions at any one time. If one attempts to express the concentration of these ions in conventional chemical ways, some cumbersome decimal fractions result. In order to avoid these cumbersome numbers, the Danish biochemist S. P. L. Sorenson devised a system called pH for expressing the acidity or alkalinity of solutions.

The pH scale goes from 0 to 14. At pH 7, the midpoint of the scale, there are equal numbers of hydrogen and hydroxyl ions, and the solution is neutral.

pH values below 7 indicate an acid solution, where there are more hydrogen ions than hydroxyl ions, with the acidity (or hydrogen ion concentration) increasing as the pH values get smaller.

pH values above 7 denote alkaline solutions, with the concentration of hydroxyl ions increasing as the pH values get larger.

The pH scale is based on logarithms of the concentration of the hydrogen and hydroxyl ions. This means that a solution of pH 5 has 10 times the hydrogen ion concentration of a solution of pH 6. A solution of pH 4 has 10 times more hydrogen ions than one of pH 5 and 10 times 10, or 100 times, the hydrogen ion concentration of a solution of pH 6.

A measurement of the pH of a solution of a strong, or highly ionized, acid measures essentially the total strength of the acid. But a pH determination of a solution of weak, or slightly ionized, acid measures only a part of the total strength of the acid, because pH is a measure of hydrogen ions only and does not measure all the acid molecules that can potentially ionize to form hydrogen ions.

In a soil, hydrogen ions exist in a number of different chemical combinations and states of adsorption on the surfaces of solid particles. The number of hydrogen ions in the soil solution at any one time is small in relation to the number held in a less active form in various nonionized molecules and on the surfaces of the solid particles.

When the soil is limed in order to bring it to neutrality, enough lime must be added to react not only with the so-called free hydrogen ions of the soil solution but also with those held in the less active forms. This is so because as the neutralization of the soil progresses, ionization of the less active forms of hydrogen likewise progresses and new free hydrogen ions are formed as long as the supply of less active forms holds out.

Thus it is possible to think of the total acidity of a soil as being composed of two parts.

One part, often called the active acidity, is made up of the hydrogen ions in the soil solution. These are the hydrogen ions measured when the pH of the soil is determined.

The second, and much larger, part of the total soil acidity is often called potential acidity. The potential acidity is due to hydrogen ions held in various chemical combinations and adsorbed on the surfaces of solid particles. These hydrogen ions are in chemical equilibrium with the free hydrogen ions of the active part of the soil acidity, and as the free hydrogen ions of the soil solution are neutralized or removed from the soil solution in other ways, hydrogen ions from the less active (or potential acidity) source enter the solution.

Most of the hydrogen ions in the potential acidity forms are held on surfaces of solid particles of clay or soil organic matter. These clay and organic particles are very small, and consequently have a large surface area per unit weight. They make up what is called the colloidal fraction of the soil. Since most of the potential acidity of soils is due to hydrogen ions held on the clay and organic particles, it follows that fine-textured soils, which are high in clay and organic matter, can have a higher total acidity than sandy soils of low clay and organic content.

There are different kinds of clay in different soils, and these different kinds of clay can hold different amounts of hydrogen ions in the potential acidity form.

Approximate Amounts of Finely Ground Limestone Needed to 5 Raise the pH of a 7-inch Layer of Soil as Indicated[1]

Soil regions and textural classes	Limestone requirements: From pH 3.5 to pH 4.5 Tons per acre	From pH 4.5 to pH 5.5 Tons per acre	From pH 5.5 to pH 6.5 Tons per acre
Soils of warm-temperate and tropical regions:[2]			
Sand and loamy sand	0.3	0.3	0.4
Sandy loam	....	.5	.7
Loam	....	.8	1.0
Silt loam	....	1.2	1.4
Clay loam	....	1.5	2.0

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[1] All limestone goes through a 2-mm. mesh screen and at least ½ through a 0.15-mm. mesh screen. With coarser materials, applications need to be greater. For burned lime about ½ the amounts given are used; for hydrated lime about 3/4.

[2] Red-Yellow Podzol, Red Latosol, etc.

Soil regions and textural classes	Limestone requirements		
	From pH 3.5 to pH 4.5 Tons per acre	From pH 4.5 to pH 5.5 Tons per acre	From pH 5.5 to pH 6.5 Tons per acre
Muck	[3]2.5	3.3	3.8
Soils of cool-temperate and temperate regions:[4]			
Sand and loamy sand	.4	.5	.6
Sandy loam	....	.8	1.3
Loam	....	1.2	1.7
Silt loam	....	1.5	2.0
Clay loam	....	1.9	2.3
Muck	[3]2.9	3.8	4.3

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[3] The suggestions for muck soils are for those essentially free of sand and clay. For those containing much sand or clay the amounts should be reduced to values midway between those given for muck and the corresponding class of mineral soil. If the mineral soils are unusually low in organic matter, the recommendations should be reduced about 25 percent; if unusually high, increased by about 25 percent or even more.

[4] Podzol, Gray-Brown Podzol, Brown Forest, Brown Podzol, etc.

[5] From USDA Handbook No. 18, p.237.

MAINTAINING ORGANIC MATTER

Soil organic matter is dynamic material. It changes continually through further decomposition, but it maintains a degree of stability in quantity and in quality through the additions of new raw materials.

Organic matter is a temporary product--a stage in a natural cycle of elements. Each increment remains in the soil while it passes through the several slow biological oxidation changes that eventually reduce it to carbon dioxide, water, and mineral elements. As it passes through the cycle, it is replaced by organic matter formed from fresh residues.

Organic matter is formed in the biological decomposition of plant and animal residues. In the decomposition process, some of the plant substances are converted rapidly to carbon dioxide, water, and mineral elements (mineralization), and other substances may be only chemically altered at first.

The microbiological activity is high when fresh plant residues begin to decay. As the micro-organisms consume the more easily decomposable materials, the level of activity gets less and less. When only the more resistant plant substances remain along with the series of new organic materials synthesized by the micro-organisms, the microbial activity becomes slow--akin to a smoldering fire--and is the cause of constant loss of organic matter from soil.

The amount of organic matter in soil at any time hinges on the speed of the microbiological activity and the amount of fresh residue material that is added each year. The principles that regulate microbiological decomposition--which affect mechanical losses of soil and determine the amount and kind of residues returned to the soil--therefore are the principles that govern the level of organic matter in soil.

A number of things affect the speed of activity of soil microbes. We can control some of them. Others depend on the weather. Some are determined by early geological processes and the kind of plant cover that prevailed before men became interested in soil organic matter. Among the factors are temperature, moisture, aeration, acidity, supply of plant nutrients, tillage, and the kind and the amount of crop residues and manures returned to the soil. Cropping systems and soil management exert strong influences on most of these factors.

Microbes are most active in a moist soil. Microbial activity is depressed when a soil is extremely wet or dry. Air is excluded from the soil pore spaces in a wet soil, and the lack of air slows decomposition.

COMPOSTING

The purpose of composting plant and animal residues is to provide the plant with food in a more easily available form than that contained in the original residues. There are, in addition, a number of other benefits to be gained from this preparation of the food.

(a) The food is presented to the plant in a steadily available form, being broken down by soil organisms during the course of the season as and when the plant requires it.

(b) The organic matter provides a useful soil conditioner in a form less readily destroyed than dung, as it contains a better balance of carbon and nitrogen compounds.

(c) Weed seeds and pathogenic organisms are destroyed by the heat and microbial activity of the composting process.

(d) The bulk of the materials used is reduced to about a third, and is in a friable condition, thus considerably reducing handling costs over the original bulk of materials.

(e) The highly concentrated and sometimes harmful compounds in some animal manures are converted to more suitable and better balanced materials for plant use.

(f) The conservation of nitrogen and other easily lost nutrients.

In order that this decomposition of residues shall come about rapidly and efficiently, three factors must be present--namely, air, moisture and sufficient nitrogenous matter, phosphates and trace elements, for the micro-organisms to build up their bodies.

Air, naturally, is required for the micro-organisms' respiration, during which they burn up the carbohydrates in the plant residues with the evolution of considerable heat. If we are to obtain this heat (140-160° F.), the air supply must be adequate. On the other hand, too much air will cool and dry the heap--the supply must be controlled. This is best achieved by wrapping small heaps with some porous material--sacking or slatted boards--or, in the case of large heaps, by situating them out of winds, or, better still, in pits with a network of air channels on the bottom to provide a steady percolation of air from the bottom upwards. It is for the reason of excessive air supply that heaps of less than half a cubic yard are difficult to heat properly except in warm weather, or unless extremely well insulated.

The actual rate of passage of air can vary within quite wide limits: an increase in flow, though carrying away the heat, also gives the organisms the opportunity to work faster and produce more heat, so that the process is to some extent compensatory. Care must be taken to avoid extremes.

In practice, a mixture of soft leafy or grassy material, and plant stems in equal proportions, or straw, with the addition of the commonly recommended one-quarter by bulk of farmyard manure, will give good results. Sawdust, coffee grounds and similar close-textured materials are almost impossible to decompose quickly, mainly because of poor aeration. The addition of sufficient nitrogenous matter and moisture for complete decomposition would effectively stop air from entering these materials. It is better, therefore, if quick results are required, to mix these materials with more fibrous matter.

The loss of nitrogen through composting close-textured materials, particularly if high in nitrogen, is well borne out in the following table.

CHANGES OF NITROGEN CONTENT IN COMPOST HEAPS

Material	Nitrogen at Start lb.	Nitrogen at End lb.	Gain or Loss lb.	Percentage Gain or Loss
Weeds	44.2	25.7	-18.5	-41.8
½ Weeds and ½ Crotalaria	42.8	28.4	-14.5	-33.8
Ditto	49.7	29.2	-20.5	-41.3
Mixed Crop Residues	28.3	29.5	+ 1.3	+ 4.4

Crotalaria is a leguminous plant. Heaps of approximately 2 tons at start.

It will be noted that the higher the proportion of nitrogen the greater the loss. While a well-aerated heap low in nitrogen finally contained the most. It has been found also that mixed wastes decompose more quickly than single materials partly, no doubt, owing to the improved texture of the heap. But it seems that many micro-organisms thrive better on a mixed diet, and these will be better catered for.

Moisture is necessary and needs to be present within comparatively narrow limits--sufficient to provide a film of moisture for the micro-organisms to travel in, but not so much as to impede aeration or even to run through the heap and cool it. While water passing through will probably not carry away much nutrient, providing the heap is warm and well aerated, should the heap become cold and the micro-organisms inactivated, there is a decided risk of this occuring. In practice, a water content of 50-70 per cent is found to be satisfactory; in effect, the materials will be holding just as much water as they can without any surplus to drain away. Too much water will also impede the activity of fungi which is necessary to decompose the ligneous fractions.

Nitrogen is the chief food element, apart from carbohydrate, required by the micro-organisms. In order to provide a balanced diet for micro-organisms the nitrogen must be between 1·2-3 and 1·8 per cent of the carbohydrate on a dry-weight basis, which represents a carbon-nitrogen ratio of about 33:1. On this basis, a ton of fresh dung containing 10 lb. of nitrogen would suffice for 1,000 lb. of straw already containing about 0·5 per cent of nitrogen. A smaller quantity will result in a somewhat slower decomposition, while a greater quantity will not be utilized by the microbes and will be destroyed by denitrifying organisms or lost to the atmosphere as ammonia or evil-smelling compounds. From the point of view of economy, therefore, it is probably wiser to err on the lower side.

It is interesting to note in this connection that a compost heap is to a large extent self-compensatory in its nitrogen requirements, as micro-organisms feeding on the material can fix considerable amounts from the atmosphere, as shown by the following table:

Amount of Dung Used	Total N. at Start lb.	Total N. at End lb.	Percentage Gain of N.	Gain N. in lb.
Full quantity	32·70	34·87	6·6	2·17
¼ quantity	29·12	32·36	11·1	3·24

It will be noted that the low-nitrogen heap has gained 1·7 lb. more of nitrogen over the full-nitrogen heap. This effect is also dependent on the aeration of the heap, as shown below.

	Pit 4 ft. Deep	Pit 2 ft. Deep
Total at start (lb.)	31·25	29·12
Total N. at end (lb.)	29·49	32·36
Loss or gain N. (lb.)	- 1·76	+ 3·24
as percentage	- 6·1	+11.1

Both these tables refer to pits containing about 2 tons of wastes.

For those farmers having abundant supplies of dung, providing the proportion of this material does not exceed a quarter by bulk to strawy or other low-nitrogen wastes, there will be little loss or gain. For the market gardener, however, who has to buy his dung, only one-sixteenth part of farmyard manure is needed, provided it is fresh, or less if the wastes contain a fair proportion of discarded vegetables, tomato haulms, etc., which are generally a good deal higher in nitrogen than straw. In practice, all that is required is sufficient to ensure satisfactory heating of the heap, permitting a large degree of latitude in proportions of materials used. On this basis, very much less of other nitrogenous materials used for composting than has hitherto been recommended seems necessary. I have myself used such compost for several years with satisfactory results, without, until recently, appreciating the reason for them.

Temperature has some influence on the nitrogen and organic matter content. Less organic matter and nitrogen is lost as the temperature rises from 113° F, (45° C.) to 167° F. (75° C.),[2] and the same applies to temperatures below 86° F. (30° C.). In the intermediate range organic matter decomposes more quickly, while the nitrogen content may increase.

The energy food of the organisms, almost entirely carbohydrates, with a little protein, can take many forms varying in digestibility. The most easily decomposed are the sugars which provide food for some nitrogen fixing organisms, notably azotobacter. There are further small quantities of starch and pectins, but the great bulk, as a rule, consists of celluloses and hemi-celluloses which provide food for a great variety of bacteria and fungi. The last group of energy-providing materials are the lignins which, so far as we know, can only be broken down by fungi. Curiously enough, the heat-loving bacteria that live in the heap in its early stages seem to prefer proteins. This possibly accounts for the fact that material low in nitrogenous compounds and activated with sulphate of ammonia or other artificial nitrogen may fail to heat up satisfactorily.

The course of events taking place in a compost heap are roughly as follows. The hemi-celluloses surrounding the cellulose fibres are strongly attacked by fungi and bacteria with the evolution of much heat. This releases the celluloses for attack, mainly by bacteria. This stage is needed after about a week, when the temperature reaches its highest peak. With a gradual fall in temperature the fungi reinvade the heap and its celluloses, and also attack the ligneous fractions, but their action is slow and lasts over several months, according to temperature and aeration. If the material contains as much as 20-30 per cent of lignins, as in wood, decomposition is very slow as the lignin encloses much of the cellulose material, thus protecting it from decomposition. Sawdust, from its finely divided nature, is a good deal more accessible, though this is counterbalanced to some extent by its close texture impeding aeration. The processes are exemplified in the table.

RATE OF DECOMPOSITION OF THE RYE STRAW AT 35° C.

Duration of Decomposition	0 days	4 days	8 days	24 days	84 days	
Total Organic Matter	100	97	78	62	49	As percentage of original organic matter
Celluloses	57	56·1	41·9	30·4	24·2	
Hemi-celluloses	21·85	18·35	10·81	8·42	6·85	

COMPOSTS, PEAT, AND SEWAGE SLUDGE

Organic materials once were the only fertilizers used by farmers. They were mainly plant and animal products high in protein and were used for their nitrogen-supplying value. The demand for many of them in making feed and the lower cost and greater availability of plant nutrients in mineral fertilizer have led to the replacement of most of them as fertilizer.

Other organic materials, such as composts, peat, and sewage sludge, continue to be used to improve soil. They are called soil amendments rather than fertilizers because of their low content of plant nutrients.

They may be incorporated into the soil or used as mulches. Heavy rates of application are the rule. Thus they have the double effect of contributing some plant nutrients and improving the physical condition of the soil.

Sometimes the amendments represent utilization of materials that otherwise would be wasted. Some have an unusual composition, and special practices are needed to use them successfully.

In composting, a microbiological process, organic materials are partially decomposed by the activity of microbes. Hemicelluloses (the gumlike substances), cellulose (the plant fiber), and lignin, (the woody material) make up 50 to 65 percent of mature plant materials. The lower percentages occur in the leguminous plants, the intermediate ones in nonleguminous crops, and the higher amounts in wood. The rest of the plant is largely water-soluble substances and protein and small amounts of fat and ash.

Microbes readily attack the water-soluble substances, hemicelluloses, and cellulose, which rot quickly.

Lignin is quite resistant to attack. Its nature changes somewhat, but it disappears only slowly.

From the readily decomposable substances, microbes get energy to carry on their activities and the carbon they need for building their cells.

About 20 percent of the carbon in the decomposed part may be synthesized into microbial cells. The remainder enters the air as carbon dioxide and becomes available for photosynthesis by new generations of plants.

About one-half of the total dry matter originally present is decomposed by the time the compost is ready for use. Three-fourths of this loss is represented by a decrease in hemicelluloses and cellulose.

Microbial cells contain 5 to 10 percent of nitrogen. So, if large amounts of energy substances are present, considerable nitrogen is needed for synthesis of cells. The amount of energy available and consequently the amount of nitrogen needed depend on the amount of material susceptible to decomposition by the microbes.

Materials like sphagnum plants and highly lignified wood tissues, which resist decomposition, have low nitrogen requirements. For the usual farm crop residues, a nitrogen content of 1.5 percent is enough for a maximum rate of decomposition. Microbes do not assimilate all the nitrogen in materials that have higher nitrogen values, and the excess is subject to loss by volatilization, leaching, or denitrification. Actually, values of 1 to 1.25 percent of nitrogen are adequate.

Mature nonleguminous plant residues are low in nitrogen and high in substances that supply energy for microbial growth. When they are incorporated into soil, microbes assimilate available nitrogen from the soil and cause a shortage of nitrogen for crop growth.

This nitrogen-depleting effect can be overcome by adding enough available nitrogen to supply the needs of the microbes. The nitrogen may be supplied by commercial fertilizer added with the organic matter if it is turned under directly. If used as bedding for livestock, the feces and urine of animals supply the nitrogen. A third (but more expensive) way to overcome the nitrogen-depleting effect is to compost the material.

Two main objectives are accomplished by composting.

First, readily decomposable substances are removed, and the percentage of nitrogen content is increased. Thus there is no danger that a nitrogen shortage will be induced when composts are added to soils.

Second, the physical nature of the material is changed. The decomposition of cellulose causes the plant material to lose its strength and to break easily. It becomes friable, crumbly, and easier to handle and incorporate into the soil. That is important when hand tools or small tillage implements are used.

With some materials, such as manure or municipal garbage, a third result of composting is the removal of obnoxious odors.

The composition of composts is variable. The moisture content is usually in the neighborhood of 75 percent, but it may be as low as 40 percent. A high moisture content makes the finished compost weigh more than the dry weight of the material originally placed in the heap. That is the basis of statements that 1 ton of plant residues will produce 2 tons or more of compost. Its value, of course, is in the dry matter.

Composts commonly contain 2 percent of nitrogen, but the content may be 1.5 to 3.5 percent in the dry matter.

The phosphorus content of dry composts is about 0.5 to 1.0 percent. Potassium values probably are twice as high. These values will be correspondingly higher if phosphate and potash are added to the compost.

The nitrogen of composts is only slowly available and never approaches that of inorganic sources of nitrogen. Its slow availability lowers the possibility of leaching and extends availability over the entire growing season. Presumably the availability of phosphorus and potassium in composts approaches that of inorganic sources.

Composts are essentially low-analysis fertilizers, and large amounts must be used to obtain adequate additions of plant nutrients to soils.

The maximum effects of composts on soil structure--increased aggregation, pore space, and water-holding ability--and on crop yield usually occur only after several years.

Composts increase crop yields as much as do equal additions of manure from the bedding of horses and cattle. Composts should be used in much the same way as manure with regard to amount and method of application and reinforcement. Because compost is like farmyard manure in physical nature, composition, and value, we sometimes call it synthetic manure.

Composts are good to use as mulches in gardens or around shrubbery. Applied 2 or 3 inches deep, they conserve soil moisture, lower soil temperatures in hot weather, help control weeds, and contribute nutrients.

Applications on small areas of large amounts of compost may supply the entire nutrient needs for the successful production of crops. If the composted materials come from a large area, the land from which they come loses its share of organic matter. One can overcome some of that loss by using rotations of sod crops whose roots restore the physical condition of the soil. The amount of organic matter that can be returned to the soil over any large area of land can be no larger than the amount produced on it. Because, furthermore, some is used by animals and man, only moderate rates of compost applications can be attained over any large area.

Before you decide whether to practice composting in practical farming operations, you should compare the soil-improving value of compost and that of the fresh residues from which it is made.

In 12 years of comparisons at the Rothamsted Experimental Station in England, turning under fresh straw to which nitrogen was added gave 10 to 20 percent greater yields of potatoes, barley, and sugar beets than composts prepared from the same amount of straw and nitrogen.

At the New Jersey Agricultural Experiment Station, fresh residues, applied on an equal organic-matter basis, produced double or triple the aggregation of silt and clay particles produced by composts prepared from the same materials.

One must also realize that (since one half the organic matter is lost in composting) fresh residues applied at the same rate will cover twice the area that can be covered by composts. When it is feasible to do so, one should return plant residues directly to the soil in preference to composting; doing so leads to greater soil improvement and saving of labor. Sufficient nitrogen and other nutrients in the form of commercial fertilizers should be added to meet the needs of the crop.

In some situations, however, composting meets a need and is a highly desirable practice.

The first is in areas where commercial fertilizers are expensive, labor is cheap, and implements are simple. Composts prepared from plant, animal, and human wastes have been used extensively for many centuries in India, Japan, and China. More than one-half the nitrogen and a higher proportion of the phosphorus and potassium returned to the soil in Japan in 1946 were supplied by composts. Composting practices in some countries include the use of town garbage and night soil; a supplementary benefit thus is improved sanitation.

Composts also are used when soil is used intensively as in market gardening, in which frequent tillage and almost complete removal of crops (sometimes even the roots) may lead to soil deterioration. Composts are used to overcome this effect.

Special composts are needed for growing mushrooms. They used to be prepared from horse manure, but more and more they are made from definite mixtures of plant products and commercial fertilizers, which supply nitrogen and potash.

The most prevalent composting in the United States is by gardeners who save garden residues, weeds, tree leaves, lawn clippings, and kitchen wastes.

Compost is produced commercially in many places.

A few operations in the United States are using manure from stockyards or large dairies. An installation at the stockyards in Chicago uses a mechanized process and can treat 50 tons of manure daily. Plans have been made to compost all of the 75,000 tons of manure produced annually at the stockyards. These preparations command a premium price and are used on gardens and lawns.

A plant at Wyster, Holland, produces 120,000 tons of compost a year from municipal refuse. The annual production of compost is sold at a low price to farmers, and the demand for it is great.

In general, it may be said that commercial production of compost is limited to situations where the cost of assembling the material is not charged to the composting operation itself.

Two sources of compostable material may get greater--wood residues (from lumbering, woodworking plants, and improvement cuttings in forests) and organic wastes in cities.

The total annual quantity of unutilized wood residues was estimated in 1956 by the Forest Service to be 1.4 billion cubic feet at sawmills and woodworking plants. An almost equal quantity was left as logging residues in the forests. About 700 million cubic feet of the residues at sawmills and plants was fine material, such as sawdust, which requires no further reduction in size for use in soil improvement. A large part of the wood residues accumulate, at points remote from possible agricultural use, but in some sections as in the North Central States, nearly all lumbering operations are on farms. Wood residues are also quite accessible for agricultural use in the Northeast and the South.

The use of these residues has been confined mainly to sawdust and shavings because of their favorable physical form and accumulation in large amounts.

All available supplies of sawdust and shavings in parts of New England are used as bedding for dairy cows. The manure is used on crops. Waste wood is also converted to chips for use as bedding. The cost may be so high, however, that the use of chips may be restricted to localities where supplies of sawdust and other forms of bedding are inadequate and transportation costs make wood chips competitive with other bedding materials.

Wood residues can be incorporated directly into the soil. They also can be composted. Both sawdust and woodchips make excellent mulches for blueberries, strawberries, fruit trees, ornamentals, and garden crops. Because woody plant materials are low in plant nutrients, they need extra nitrogen and phosphate when they are composted or added to soil.

Municipal organic wastes of garbage and street refuse are composted for agricultural use in many European cities and in the Far East. In this country they have been disposed of mostly by land filling, soil burial, or incineration, but there is an increasing interest in the possibility of disposing of them by composting because of the growing scarcity of areas to be filled in, objections to air pollution produced by incineration, and the possibility of reducing costs of waste disposal from the sale of the compost.

The staff of the Sanitary Engineering Research Project of the University of California in 1953 completed a series of experiments on composting municipal wastes. They found that a wide variety of wastes could be composted successfully. Shredding the material (after cans and bottles have been removed) to permit uniform mixing was found desirable. No further modification was found necessary. Turning the heaps every 3 or 4 days meant that finished compost could be produced in 2 or 3 weeks. The composts contained as much plant nutrient as did composts from crop residues. Its value for soil improvement should equal those of manure or composted farm residues.

Almost any natural organic product can be composted with proper care--cornstalks, straw, hay, tree leaves, wood residues, coconut husks, animal and human excreta, garbage, wastes from wineries and breweries, and many more. The microbes are not choosy.

For making composts, you must provide proper aeration, moisture, nutrients, and temperature for microbial decomposition. Those factors and the nature of the material affect the time required for preparation and the final composition. Composting is usually carried out by piling organic materials into heaps where reasonable control of these factors can be maintained.

Air should penetrate the entire compost heap to allow microbes to act and finish the compost in a minimum of time. Aeration depends on size of air spaces within the heap, the height of the pile, and the moisture content.

The coarse materials, like cornstalks, cause large air spaces, excessive aeration, and rapid loss of moisture and heat from the heap. They should be cut to 6-inch lengths or mixed with finer materials before composting. Excessive aeration can be reduced by compacting the pile and by increasing its height. Fine materials, such as sawdust, are hard to aerate and may be mixed with coarser materials or turned oftener. Cereal straws and tree leaves have good properties for composting.

Compost heaps should be built no more than 6 feet high so air can penetrate to the bottom of the pile. Width and length may be adjusted for convenient handling.

Excessive moisture cuts aeration by filling air spaces in the material and by increasing compaction.

Only a slow partial decomposition takes place when aeration is insufficient. Intermediate products of anaerobic microbes, such as organic acids and reduced nitrogenous and sulfur compounds, are formed. Many have offensive odors.

The physical nature of the composting material frequently is altered little under anaerobic conditions, and it remains hard to handle. Poor aeration is overcome by turning the heap.

The composting material should be kept damp but not wet enough to cause liquids to trickle down and collect at the bottom of the heap. The weight of the moisture should be 1 to 2.5 times that of the dry organic material. Decomposition is slowed down when the heap is drier than that: anaerobic conditions set in, particularly at the bottom of the heap, when it is wetter. Water is best applied to the layers as the pile is built up.

Many fresh dry plant residues are somewhat hard to wet. They can be wetted best by applying the water in a fine spray. If necessary, water should be added on 2 or 3 successive days at the start of the composting period.

Letting water run out at the bottom of the pile should be avoided because nutrients are lost. Fresh green materials, such as grass clippings, contain too much moisture for proper composting. They should be left to wilt before piling or should be mixed with about one-third their weight of dry material. Rainfall may increase moisture in the heap. If the moisture becomes excessive, it can be reduced by turning and loosening the pile. Small heaps that have a high proportion of exposed surface may become unduly dry. Water should be added to them as needed.

Most plant residues will form composts in time if they simply are put in a heap and kept moist.

Sometimes nutrients are added. Mature residues of nonleguminous plants require the addition of about 15 pounds of actual nitrogen per ton of dry material--equal to the nitrogen in 70 pounds of ammonium sulfate or calcium cyanamide, 45 pounds of ammonium nitrate, or 30 pounds of urea. Any of them are satisfactory. Calcium cyanamide and urea give a slightly basic reaction, which promotes rapid decay. If ammonium sulfate is used, an equal amount of finely ground limestone should be added to neutralise the acidity arising from the sulfate anion.

Residues of leguminous plants and young nonleguminous plants may contain 1.5 to 3.5 percent of nitrogen and need no additional nitrogen. Substantial losses of nitrogen occur if such residues are composted directly, because the amount of nitrogen present is in excess of that assimilated by the microbes. Such materials should be mixed with residues of low nitrogen content. Two or three parts of mature, nonleguminous residues mixed with young plants or with leguminous plants give a satisfactory mixture.

Other organic nitrogenous substances, such as cottonseed and soybean meals and dried blood, may be added to composts to give the proper nitrogen content. The cost of nitrogen in these forms is greater than in the inorganic form. Liquid and solid excreta of animals and sewage sludge also may be used to supply nitrogen to composts.

The microbes need so little phosphate and potash that ordinary plant residues supply enough for composting. To sawdust or plant residues that become leached before composting, it may be wise to add phosphate and potash—about 20 pounds (or 3 gallons) of superphosphate and 5 or 10 pounds of potassium sulfate or potassium chloride to a ton of residue.

The phosphate and potash increase the fertilizing value of the resulting compost. A complete fertilizer with an analysis such as 10-6-4 may be used to supply nitrogen, phosphate, and potash. The fertilizer should be added to give the proper amount of nitrogen in the beginning compost. Extra care should be taken to prevent leaching. If that cannot be done, it is preferable to reinforce the compost when it is applied to the soil instead of in the pile.

Rotting proceeds slowly at temperatures near freezing. Microbial processes increase at higher temperatures. The rate nearly doubles for every rise of 18° F. in temperature.

Microbes themselves produce heat as a byproduct of the decomposition. They release large amounts of heat in the pile; since it is nearly self-insulating, the temperature of the pile rises. Microbes that grow best at ordinary temperatures initiate the decomposition and carry it on until a temperature of about 115° to 120° is reached. That temperature kills them, and another group of microbes takes over. They are called thermophiles, or thermophilic organisms, because they can carry on at high temperatures. They raise the temperature inside the heap to 140° to 170°. This rise in temperature, which usually persists 2 or 3 weeks, indicates that the composting is proceeding normally. It greatly shortens the time required for the decay of the plant material. The rapid dissipation of heat in small or open heaps may keep temperatures down too low.

The high temperature also kills disease-causing organisms, insects, and weed seeds, except in the outer parts and the bottom of the heap. When the heap is turned, those parts should be turned to the center of the pile so that they also will be subjected to the high temperatures.

Residues of diseased plants should be composted only if they can be completely subjected to the high temperatures in the interior of the heap. That is seldom possible with small piles; if so, they should be burned to avoid spreading disease.

Turning the compost heap hastens the decomposition by increasing the supply of air for the microbes. Heaps may be turned every 3 or 4 days in commercial operations. In some mechanized processes, air is blown continuously through the composting mixture. In farm and garden practices, the compost should be turned at least once about every 3 weeks after its preparation. More frequent turning is desirable to assure mixing and more uniform decomposition of the heap. The number of turnings may be adjusted to facilities available and the desired time for completing the compost.

Occasionally some practices are advocated that are not essential. Inoculation with prepared cultures of microbes is sometimes said to hasten the process and lead to a better product.

Experiments at the University of California tested soil, horse manure, partially composted material, and a commercial preparation of selected cultures as inoculants. None had any significant effect on the course of composting. It appears that the materials used in composting have enough of the microbes on their surfaces to start and continue decomposition.

Mixing small amounts of soil into composts is unnecessary, but the soil may help conserve nitrogen and other nutrients. A thin layer of soil on the outside surfaces of a heap will aid in retaining moisture. A shallow pit does the same, but the pit should be in a well-drained place, because accumulation of water in a poorly drained pit will produce anaerobic conditions.

When is the composting process completed? In large, well-prepared heaps, a drop in the interior temperature to values near air temperature and easy crumbling of the materials in the hand indicate completion.

Full composting in small heaps usually requires 3 months under favorable conditions of moisture and temperature. Composts prepared late in the fall in regions of cold winters may not be ready for use until early the next summer. Under commercial conditions, with large heaps and frequent turning, composting time may be shortened to 2 or 3 weeks. With some mechanized processes, only 10 days are required for fresh material, and that may be shortened to 3 days if the beginning material is already partly decomposed.

Bins of simple construction are desirable for home or garden-scale composting. A bin will help to maintain moisture at the edges of the heap and prevent blowing. It should be about 4 feet wide, 5 feet high, and as long as needed to hold the material available for composting. No floor is needed.

It is well to have two bins side by side with one common wall. The compost may be forked then from one bin to the other for turning and mixing. The compost that is ready for use may be kept in one bin while fresh compost is started in the other.

Snow fencing with posts at the corners makes a satisfactory bin. A variety of timbers, arranged in log-cabin fashion, or boards nailed to corner posts provide satisfactory enclosures. Only narrow cracks should be left between the timbers or boards. More permanent structures may be built of concrete blocks or bricks. Small openings should be left near the bottom of such walls to permit penetration of air. One end of the bin should be closed with removable boards to permit access for mixing and removal of the compost.

Peat is a widely used organic soil amendment. It is made up of plant remains that have accumulated over the centuries under relatively airless conditions in bogs.

Peats may be divided into two main types, according to the kind of plants from which they were formed. One is sphagnum peat—or peat moss, or highmoor peat--which is derived from species of the sphagnum plant. The other, formed from the sedges, reeds, mosses, or trees is called lowmoor peat.

Peat derived from trees is sometimes grouped separately as forest peat, or peat mold. It is intermediate in composition between sphagnum peat and that derived from sedges and reeds. Forest peat contains many finely divided particles of wood and is often used for mulching.

Sphagnum peats of a dry-matter basis have an ash content usually below 5 percent, nitrogen 1 percent or less, and phosphorus and potassium below 0.1 percent. They are very acid, with pH values between 3.0 and 4.5. Fresh sphagnum peats have a high water-holding capacity equal to 15 to 30 times their own weight, but that is cut in half following drying. Cellulose and hemicellulose make up about 40 percent of sphagnum peats, but they are resistant to decomposition by microbes.

Lowmoor peats are more variable than sphagnum. Their dry matter contains 5 to 40 percent of ash, 1.5 to 3.5 percent of nitrogen, and less than 0.1 percent of phosphorus and potassium. They can hold 3 to 8 times their own weight of water. Their pH values range from 3.5 to 7.0. Because most of the cellulose and hemicellulose in them has been decomposed, they have a high amount of ligninlike substances.

Peats improve the water-holding ability of most soils and give better physical structure to fine soils. Heavy applications equal to 25 to 50 percent of the volume of the soil often are made with that in mind. They are used mostly on specialty crops and home grounds.

Undecomposed or slightly decomposed forms of sphagnum, if incorporated into the soil, require small amounts of nitrogen. Acid peats are used for acid-loving plants as a direct growth medium or by mixing into the soil or as a mulch on the place where they are grown. The acidity of such peats may need to be neutralized with ground limestone if they are to be used for ordinary plants.

Peats, especially the coarser grades of sphagnum, are good livestock bedding and poultry litter. In 1950 in the United States an estimated 161,000 tons of peat were used for soil improvement and 31,000 tons for stable bedding and poultry litter.

Sewage sludge is the solids remaining from the treatment of sewage in disposal plants. Various methods of digestion and removal of the solids reduce the organic matter in the plant effluent to a safe point. The resulting sludge is filtered off and may be burned or sold or given away for use as a fertilizer.

The value of the sludge for soil improvement depends on the method used for treating the sewage.

Activated sludge comes from disposal plants in which aerobic treatment is obtained by bubbling large quantities of air through the digesting sewage. The sludge is then allowed to settle in large settling tanks, drawn off, and filtered. The filtered material still contains 80 to 85 percent of water. If it is to be sold as fertilizer, it is dried by heat to a moisture content of 5 to 10 percent. Activated sludge contains 30 to 40 percent of ash, 5 to 6 percent of nitrogen, and 1 to 3.5 percent of phosphorus.

Digested sludges come from disposal systems in which solids are allowed to settle out and are then digested anaerobically. On a dry-matter basis, they contain 35 to 60 percent of ash, 1 to 3 percent of nitrogen, and 0.5 to 1.5 percent of phosphorus. They are allowed to air-dry on sand filter beds outside or in greenhouses where they are protected from rain. Because of their low content of plant nutrients, they are seldom sold for fertilizer.

Activated sludge has a higher nutrient content, lower moisture, better physical condition, and no odor. Available nitrogen in activated sludge is almost equal to that in cottonseed meal and costs about the same. When it is added to soil, about one-half the nitrogen is nitrified in 4 weeks. More than 50,000 tons of activated sludge are produced annually by the sewage disposal plant of Milwaukee, Wis. There is a wide demand at good prices for this product for fertilizing grass in lawns, parks, and golf courses.

All sewage sludges are low in potassium because compounds of potassium dissolve readily in water. They must then be supplemented with a potash fertilizer when used on soils that have too little potassium. Additional phosphate also is needed on some soils, depending on the amount of sludge used.

Sludges contain appreciable quantities of the minor elements, copper, boron, manganese, molybdenum, and zinc. A few experiments indicate that they are available for plant growth.

Sanitary aspects must be considered when digested sludges are applied. Pathogenic organisms may escape the treatment process. It is not advisable to use digested sludge on root corps or low-growing vegetables that are to be eaten raw. Incorporation into the soil 3 months ahead of planting leads to destruction of the disease organisms. Digested sludges give rise to bad odors, which can be overcome by immediate incorporation into the soil. Activated sludges have no bad odor and microbes are killed in the heat treatment.

WATER AND FARMING

WATERSHEDS

A watershed is a drainage area containing a few thousand or a few hundred thousand acres, from which water drains toward a single channel. It is a social and economic unit for community development and conservation of water, soil, forests, and related resources. Conservation begins on the watersheds.

Conservation based on management of watersheds goes far back. In 1867 a commission established by the Wisconsin State Legislature pointed out the relationship between forest cover and streamflow. A New York State Commission in 1872 investigated the desirability of maintaining the forests of the Adirondack Mountains for the purpose of benefiting the Hudson and other rivers and the Erie Canal. The American Forestry Congress in 1886 adopted a resolution directing attention to the value of public lands at the sources of streams in the preservation of water supplies and urging that those lands be kept for public use "with a view to maintaining and preserving a full supply of water in all rivers and streams." In 1891 the first forest reserves were set aside under authority granted by the Congress. In 1897 the Congress, in enacting the Organic Administration Act for national forests, established as one of the principal purposes of such forests the "securing of favorable conditions of water flows."

SURFACE IRRIGATION

There are three general methods of applying irrigation water to the land.

In surface irrigation the soil is the reservoir from which the plants draw the water they need. The soil also conveys and distributes the water over the field.

In sprinkler irrigation the water is conveyed above the field in pipes, and the soil acts as a storage reservoir.

In subirrigation the water flows underground, and the capillary water moves upward toward the surface of the land to meet the needs of the crops.

Surface irrigation, with which this chapter deals, includes the general methods of flood and furrow and corrugation irrigation.

In flood irrigation, the water is permitted to cover the surface of the land in a continuous sheet. Theoretically the water should be standing at every point in the fields just long enough for the soil to absorb the whole amount of water needed to refill the root zone. But under practical field conditions it is seldom possible to meet the theoretical requirement completely--some parts of the field usually receive too much water if all parts receive adequate water. If the size of the irrigation stream is properly balanced against the intake rate of the soil, the total depth of water to be stored in the root zone, and the area to be covered by the stream, however, the results will be reasonably uniform and efficient.

Flood irrigation includes several methods: Border strip, basin, contour or bench border irrigation, flooding from contour ditches, wild flooding, and border ditch.

The object of border strip irrigation is to advance a sheet of water down a narrow strip between low ridges or borders and to get the water into the soil as the sheet advances. The strip must be well leveled between the border ridges and the grade down the strip must be fairly uniform to avoid ponding. The ridges should be low and rounded so they can be planted with the strips and no land lost to production.

Border strip irrigation is well adapted for all close-growing crops and is used for some row crops, such as cotton. Hay and grain can be irrigated on uniform slopes up to 3 percent.

Established pasture can be irrigated on uniform slopes up to 6 percent. The method can be used on soils of coarse or fine texture. It utilizes large water streams safely. Its requirements as to labor and time are low. It provides for uniform wetting and efficient use of water.

Basin irrigation is adapted especially to flat lands. It consists of quickly filling a diked area with water to the desired depth and allowing the water to percolate into the soil. It is desirable for close-growing crops and orchards on medium- to coarse-textured soils and for rice that is grown on fine-textured, slowly permeable soils. When the basins are properly graded and built to the right dimensions for the kind of soil and water supply, water can be applied efficiently and alkali can be controlled.

Contour, or bench border, irrigation is adapted to fairly uniform, moderate slopes with deep soils. Border strips are laid out across the slope on a controlled grade, and the ridges are constructed parallel to each other. If the strips are laid out on a grade, they operate about the same as does border strip irrigation. If the strips are short and level, it is like basin irrigation.

Flooding from contour ditches is used often on close-growing crops on sloping or rolling lands not subject to the degree of leveling necessary for other methods of irrigation. Water is flooded downslope between closely spaced field ditches running along the contour of the land. The ditches prevent the water from concentrating and causing erosion. Fairly uniform wetting is possible, but labor costs of irrigating are rather high. In general, this method should not be used if a more desirable method can be used.

In wild flooding, the stream of water is diverted from its course and allowed to spread out over the field at random. It is not recommended, because the low spots in the field will get too much water and the high spots will receive none.

The border ditch method is used in some of the older irrigated areas of the West, but it is not generally recommended. Parallel ditches 25 to 200 feet apart are run down the field in the direction of the land slope. The strips of land between the ditches are irrigated by diverting the water at intervals from either side of the ditch. The method uses water and labor inefficiently. The ditches often erode on the steeper slopes and silt full on the flatter slopes. They take a considerable area of land out of crop production and act as a weed nursery for the rest of the field.

Furrow irrigation is the most common method of applying water to row crops. Water is applied in the furrows between the rows of plants. As water runs down the row, part of it is being absorbed all along the furrow and is moving through the soil to refill the moisture-storage reservoir of the soil under the growing plants. It is adapted to all row crops, truck crops, orchards, vineyards, and berry patches on gentle slopes on all but the coarser soils.

Cultivation of the furrows to control weeds keeps the soil loose. When the furrows run down the slope, serious erosion can occur unless the size of the irrigating stream is carefully controlled.

Furrow irrigation is usually expensive from a time and labor standpoint. Properly operated, it is fairly efficient in its use of water.

Contour furrow irrigation is an adaptation of furrow irrigation, in which the furrows are laid across the slope on a carefully selected grade. A reduction in the grade of the furrows makes them much less subject to erosion by irrigation water and rain.

Corrugation irrigation is well adapted to close-growing crops on sloping and rolling lands and to soil slow to take water. The water is applied in small furrows running down the slope from the head ditch. The purpose of the furrows is not so much to carry the stream of water as to guide it. Some overtopping of the furrow may occur. Corrugation irrigation is suitable for fine-textured soils that take the water slowly and tend to seal over and bake when flooded. It provides uniform wetting and prevents erosive water accumulation on land too rolling or steep for borders or basins and makes use of small irrigating streams. It is relatively expensive in labor.

A farm distribution system is necessary to convey the irrigation water to the various fields from the point at which the water is available on the farm.

The system must be designed to carry enough water to meet the demands of the crop to each field without erosion and allow for efficient application. It must be laid out in accordance with good farm management practices. It must provide for conveying and regulating the irrigation stream and for the roads and drains that are needed. It must be located to give minimum interference with seeding, tillage, and harvesting.

Open ditches are the most common means of conveying irrigation water. In many areas the ditches to each field are permanently constructed and maintained. They form field boundaries and have permanent conveyance and control structures. Often their banks are seeded to perennial grasses to control weeds and provide extra stability. They usually have flat bottoms. Side slopes may be in the ratio of 1.5 to 1 or flatter, and are designed to carry the stream at a nonerosive velocity. Permissible velocities may be as high as 6 feet a second on shales and hardpans and as low as 1.5 feet a second in fine sands.

In areas where the seasonal requirements are low and only one or two irrigations are required, it is often wise to utilize temporary ditches for distributing the water to the fields. Such ditches are built with farm-type ditchers; they may have flat or rounded bottoms or a V cross section.

In medium- and fine-textured soil, side slopes are sometimes quite steep to reduce the overall width of the ditch and to facilitate the installation of temporary checks or other structures. These ditches are plowed in after the irrigation season is completed as a measure of weed control and to remove obstructions to harvesting operations.

Temporary ditches also are used for conveying the water from the edge of the field to the individual furrow or border. They are usually installed after the crop is planted, are used during the irrigation season, and are removed before harvest.

Conveyance structures of various types are usually necessary in open ditches to deliver water at the desired elevation on each field. Often an intervening low area between the water source and the upper part of the field requires the use of flumes or inverted siphons to carry the water across the draw or swale. These permanent structures should be well designed and constructed to fulfill their purpose and eliminate excessive maintenance.

When any minor depressions are encountered, a compacted earth fill is often placed and the ditch constructed on its top. Drainage water can be carried from one side of the embankment to the other by a culvert placed below the bottom of the irrigation ditch. Such installations, while relatively cheap to construct, pose problems of maintenance and are subject to damage from rodents and burrowing animals.

When ditches are constructed across porous soils, the loss of irrigation water by seepage may be serious. If so, permanent ditches may be lined with such less perimeable material as clays or bentonites. The ditches may be lined with concrete or asphaltic concrete or may be sealed by means of a thin flexible membrane. Membrane linings are usually buried a few inches below the ditch surface to protect them from mechanical damage.

Important parts of any farm distribution system are the crossing structures, which permit the movement of machinery, produce, and livestock across the irrigation stream. Often they can be made a part of other structures. Sometimes culverts or bridges are provided.

Control structures placed in open ditches may be of many types. Their function is to measure the flow, provide a means of diverting the water from the ditch, or to lower safely the water from one elevation to another.

To make proper application of the water, the irrigator should know the size of the stream he is using. Measuring devices should be part of the distribution system and should permit the farmer to determine the flow being delivered to any point on his farm. Parshall flumes or weirs are often used for the purpose. Other structures in the system are sometimes calibrated so that reliable estimates of the flow may be made.

Water-control structures may be classified as division boxes, turnouts, and checks. Division boxes are used if the stream is divided into two or more sublaterals and may or may not be equipped with gates to control the flow. Turnouts provide a means of delivering water from the ditch to the area to be irrigated or into a temporary ditch. Checks are adjustable dams placed in the irrigation ditch to provide a means of controlling the depth of water serving the turnouts. Often it is advantageous to install structures that perform two or more of the functions.

Permanent ditches usually are equipped with permanent or semi-permanent structures of concrete, masonry, timber, or metal. Temporary ditches usually have portable structures, which may be quickly installed or moved as needed.

Siphon tubes or spiles often are used to deliver the water from temporary ditches. The tubes, which carry water over the ditch bank by siphonic action, are made of a variety of materials in a number of sizes. Small tubes may deliver as little as a gallon a minute. The larger ones carry as much as 2 cubic feet a second. Spiles, or tubes laid through the ditch bank, also are commercially available for a similar range of flows.

A temporary check dam of a common type is made from a sheet of flexible plastic or canvas attached to a supporting rod or beam. The dam is placed across the ditch in such a way that the rod or beam rests on the ditch banks and the plastic or canvas material is tucked into the ditch side and bottom upstream. Such devices usually can be adjusted so that some of the flow may be carried downstream through a sleeve or over the top of the dam. Other types of temporary checks are made of sheet metal, pipe, fabric, or combinations of those materials.

Open ditches must carry the required flow of water without scouring. Erosion-control structures often are necessary to reduce the grade in the earth sections of the ditch. The structures have many forms and materials. A common type is a weir notch, equipped with an apron at a lower elevation so that the water may be dropped vertically to reduce the velocity of the water in the earth ditch to a safe value. Others consist of paved ditch sections on steep grades--often called chutes--or buried pipes, which will lower the water. Regardless of the type, the structure must be able to carry the required flow and provide for dissipation of the energy in the falling water before it enters the earth ditch section below.

Pipelines are usually more expensive to install but have advantages over open-ditches. Pipelines may be used to convey water by gravity alone or under pressure across a swale or to a higher elevation. They are essential when pressure is necessary to operate the system.

Permanent pipelines usually are buried and are equipped with necessary hydrants, relief stands, and other devices to control the water and protect the line. Permanent lines are commonly made of concrete, clay, asbestos-cement, or steel pipe. Plastic and aluminum pipe have become popular.

Portable surface pipes or hoses provide a good method of conveying the water to the field or to the individual border, basin, or furrow. They are made of light materials--steel, aluminum, plastic, or canvas--and often are equipped with patented coupling devices for ease in connecting. They may be manufactured with small, adjustable gates, which permit the release of a small stream into each individual furrow.

Pipelines must be carefully planned to meet the requirements of the crop, fit the site conditions, and provide for economy of installation and operation. Because they eliminate losses from seepage and evaporation and provide excellent control of the water, they have found favor in many areas where water is scarce or expensive.

The layout and management of the system needs careful planning as to soils and topography, intake rates and water-holding capacities of the soils, the amount of water that can be run in each furrow or border strip without causing erosion, and the relationship between length of run and size of irrigation stream to get the proper amount and distribution of moisture in the root zone.

Excessive irrigation wastes not only water. It also causes the leaching of water-soluble nutrients beyond the reach of the plants. Too heavy irrigation on higher land often causes waterlogging of rich, lower lands. Usually such a situation can be corrected only by a costly system of drains and reclamation.

How to apply irrigation water to crops without causing soil to erode is a big problem. Improvement in the fertility and structure of soil usually helps it absorb water faster. As the rate of intake increases, larger streams of water must be delivered to the furrows and borders to get uniform irrigation. Even though erodibility may be reduced by good soil management, the effect of the larger streams more than offsets any such gain. Thus the soil characteristics that influence irrigation methods are not stable. Conditions change from year to year with the cropping practices and even from irrigation to irrigation in a single season.

Theoretically it would be desirable to change the irrigation layout of a field at each successive irrigation for maximum efficiency. From a practical standpoint, continuously changing the length of run and spacing of furrows is not possible. Therefore the irrigation engineer, taking into account all of the influencing factors and the magnitude of change that might take place throughout the season and the rotation period, must choose practices that will be safe and reasonable for the conditions of the site.

Some suggestions are given for the layout and stream size generally most desirable.

Furrow and corrugation layouts are handled together because they are both subject to erosive action and both are thought of as generally carrying the water from one end of the field to the other.

The allowable size of streams on sloping lands largely depends on the slope at which the furrows are laid out. The general relationship of maxiumu allowable furrow stream and slope is $Q = \frac{10}{S}$, in which

Q is the maximum nonerosive furrow stream in gallons per minute and S is the slope of furrow in percentage.

Thus, if the slope of the furrow is 0.2 percent, the furrow will carry 50 gallons a minute without serious erosion. With a slope of 2 percent, the furrow will safely carry only 5 gallons a minute.

With the flatter slopes, erosion probably will not be a factor--the carrying capacity of the furrow limits the size of stream that can be carried.

Maximum allowable length of run depends on several factors, including the maximum allowable stream size, the rate at which water is absorbed by the soil, and the amount of water to be stored each irrigation. The last two factors particularly vary throughout the season. The accompanying tabulation gives the values suggested for average conditions.

Spacing of furrows and corrugations sometimes can be varied within certain limits. Spacing greater than 30 inches generally is not desirable for most annual crops, because the root zone is so limited during much of the season. Of course many row crops are grown at a greater spacing and the furrow spacings are fixed.

In general, the coarser the soil, the closer the corrugations should be spaced for efficient irrigation, but spacings of less than 15 inches are seldom practical to construct and maintain.

Flow control from the field lateral to the individual furrows and corrugations is usually by siphons, spiles, or open cuts in the bank. For efficient and safe irrigation, however, positive controls are needed. Furrow streams of varying size do not give uniform application of water, and the larger streams may cause excessive erosion.

Border strip layout depends on the intake rate of the soil, the slope, and the depth of application.

The size of the border strip should not be greater than the maximum allowable or available stream will cover uniformly during the irrigation set, without excessive losses. The width is largely governed by the slope of the land and the amount of water that can be safely carried through turnouts to the strip. The length is limited by the size of stream per unit of width of strip that will flow without causing erosion.

For example, with slopes of 0.5 percent, a flow of 0.1 cubic foot per second per foot of border strip width may be safely used; with a slope of 2.0 percent, the safe value falls to about 0.035. Thus a longer run (length of border strip) is possible on the flatter slopes.

The height and shape of the border dikes are important. A common error is to build the dike too low to control the flow. The dikes must be higher for the flatter slopes than for the steeper ones. The base of the dike also should usually be broad, so that farming operations can be carried on over the dike. Seldom should the sides of the dike be steeper than 2 horizontal to 1 vertical. Thus, on the steeper land where a minimum height of dike is 3 inches, the base would need to be at least 18 inches wide. On flatter lands where a 6-inch-high dike is needed, the minimum base width of the dike should be about 36 inches.

Properly constructed dikes allow for crop growth right over the dike and still control the flow of water during irrigation.

The size of the irrigation stream depends on the soil, size of border strip, and depth of application. Soils of high intake rates require large streams to get the water over the land rapidly if excessive deep-percolation losses are to be avoided. Likewise for shallow irrigations large streams must be used. Small streams are desirable for deep applications.

The table on the next page suggests the relationship between size of stream needed to irrigate border strips of various sizes under different site conditions:

Control of flow into the border strips can be by open cuts in the field lateral, through open or pipe turnouts, or through siphons over the bank. In loose, sandy soils and in places where large flows are desirable, siphons that will carry up to 2.0 cubic feet a second each have been found useful. Such siphons require the use of a priming pump, but are relatively easy to handle and positive in action. The investment in an adequate number of siphons to irrigate a large field is relatively small, compared to the cost of adequate permanent turnouts. The use of siphons lets the head ditch remain open, so that it can be cleaned by machines instead of hand labor.

Basin irrigation depends on using relatively small, level areas surrounded with dikes high enough to store the desired depth of water on the land. The irrigation stream is large enough to fill the basin quickly and then be turned into the next.

The basin dikes are often higher and steeper than those used with border irrigation, as it is not so common to farm over basin dikes.

Stream sizes desirable for basin irrigation should be considerably larger per unit of land area than with border irrigation. Possibly a good guide for the proper stream size would be to use at least twice as large a stream per unit of area as was suggested for the flatter grades with border irrigation.

Stream control to the basins is usually through some type of open or pipe turnout that has adequate capacity for the large streams required.

Border Irrigation Relationships for Various Soils, Slopes, and Depths of Application

Soil Texture	Slope of Land	Depth of Application	Suggested border-strip size		Size of irrigation stream
			Width	Length	
	Percent	Inches	feet	feet	Cubic feet per second
Coarse	0.25	2	50	500	8.0
		4	50	800	7.0
		6	50	1,320	6.0
	1.00	2	40	300	2.75
		4	40	500	2.50
		6	40	900	2.50
	2.00	2	30	200	1.25
		4	30	300	1.00
		6	30	600	1.00
Medium	0.25	2	50	800	7.0
		4	50	1,320	6.0
		6	50	1,320	3.5
	1.00	2	40	500	2.5
		4	40	1,000	2.5
		6	40	1,320	2.5
	2.00	2	30	300	1.0
		4	30	600	1.0
		6	30	1,000	1.0
Fine	0.25	2	50	1,320	4.0
		4	50	1,320	2.5
		6	50	1,320	1.5
	1.00	2	40	1,320	2.5
		4	40	1,320	1.25
		6	40	1,320	0.75
	2.00	2	30	660	1.0
		4	30	1,320	1.0
		6	30	1,320	0.67

Flooding from contour ditches is common practice on some of the older irrigated lands of the West, where the topography is rather rough. The contour ditches should be set with practically no grade if they are not too long. For longer ditches, a slope of 0.1 foot per 100 feet is usually adequate and is easier to handle.

Spacing between contour ditches should not be too great. With fine-textured soils on grades of 1 to 2 percent, the spacing should not exceed 250 feet. On the same grades, ditch spacing on the coarser soils should not exceed 100 feet. For 5-percent slopes, the distances should be 150 feet and 50 feet, respectively.

The size of stream required at any one turnout along the contour ditch need not be large, because the area of land such a stream is expected to cover will be small. The stream sizes, per unit of area, suggested under border irrigation generally apply to the contour ditches.

Flow control from contour ditches is often by cuts in the ditch banks, particularly if the banks are sodded. Siphons have been satisfactory in some localities.

Specifications for surface irrigation methods cannot be entirely rigid.

Many of the factors affecting the relationships of length of run, the size of stream, and spacing of corrugations vary widely throughout the irrigation season and throughout the crop rotation period. The foregoing specifications, however, will satisfy average conditions when good farming is practiced.

Border strip irrigation generally will not function properly when the slope in the direction of flow is more than 2 percent. Pasturelands sometimes utilize borders on steeper grades up to about 6 percent, but the distance between border ridges must be reduced to about 10 to 15 feet. The steepest downfield slope on any one border strip should not be greater than twice the flattest, and the grade should either increase or decrease consistently from one end to the other without undulation. A cross slope as much as one-tenth of a foot is allowable within an individual border strip; that often provides the limiting factor for the width of border strips. For example, a field with a cross slope of 0.2 percent could not have border ridges more than 50 feet apart.

Furrow Irrigation Relationships for Various Soils, Slopes, and Depths of Application

Soil texture		Coarse				Medium				Fine			
		Depth of irrigation application, inches											
Furrow Slope	Maximum allowable non-erosive furrow stream	2	4	6	8	2	4	6	8	2	4	6	8
		Maximum allowable length of run, feet											
Percent	Gallons per Minute												
0.25 . . .	40	500	720	875	1,000	820	1,150	1,450	1,650	1,050	1,500	1,750	2,140
0.50 . . .	20	345	480	600	680	560	800	975	1,120	730	1,020	1,250	1,460
0.75 . . .	13	270	380	480	550	450	630	775	900	580	820	1,000	1,150
1.00 . . .	10	235	330	400	470	380	540	650	760	500	750	850	990
1.50 . . .	7	190	265	330	375	310	430	530	620	400	570	700	800
2,00 . . .	5	160	225	275	320	260	370	450	530	345	480	600	675
3.00 . . .	3	125	180	220	250	210	295	360	420	270	385	470	550
5.00 . . .	2	95	135	165	190	160	225	270	320	210	290	350	410

Corrugations can be successfully used on slopes as high as 8 percent in places where runoff from rains is not a serious problem and where the irrigation water is carefully controlled. The slope of the corrugation within the run should not undulate. When the grade increases down the field, the steepest portion should not have a slope greater than twice the flattest, and the total change should not exceed 2 percent. When the grade decreases, the steepest part should not be more than one and one-half times the flattest, or a total change of 1 percent. If the grade of the corrugation is more than 2 percent, a cross slope as high as 0.5 percent may be permitted, but on flat grades the cross slope should not be greater than one-fourth the down-field grade.

Furrows, like border strips and corrugations, should not have an undulating profile. They may be used on slopes up to 3 percent when erosion from rain is not a problem. The steepest grade in the profile on increasing slopes should not be greater than twice the flattest; on decreasing slopes, the steepest should be less than one and one-half times the flattest.

The maximum allowable cross slope depends on the depth of the furrow. When furrows are about 9 inches deep, cross slopes up to 8 percent are satisfactory on fine- and medium-textured soils. On coarse-textured soild, the upper limit of cross slope is 5 percent; on very coarse soils it is 2 percent. With medium-depth furrows, 6 inches, the allowable cross slopes are 3 percent, 2 percent, and 1 percent, respectively, for fine or medium, coarse, and very coarse soils. Shallow furrows, 3 inches, may have cross slopes of 0.5 percent on medium and fine soils and 0.3 percent on coarse soils. These requirements are very important when the contour irrigation is the method to be used.

Basins or level borders require grades less than 0.1 percent with no cross slope. If contour levees are used, such as in rice basins, the land slope should not exceed 1 percent, and the levees should be spaced so that the vertical interval between dikes is not more than 3 inches.

Surface irrigation should be supplemented with a complete water-disposal system to remove waste waters and to eliminate unwanted ponding. The drains should be designed to carry off short, peak flood flows as well as irrigation waste water. Provisions are needed to allow basins or levee systems to be drained when desired. Drains often need some protection--vegetation or some structure, to carry the water without erosion. Drains should be equipped with crossings so that farm equipment can be moved over them.

On many farms three-fourths of the irrigation water is wasted. A good way to prevent such waste is to prepare fields properly before they are irrigated.

The preparation of land for irrigation--or land leveling, as it is commonly called--is the reshaping of the land surface to facilitate or improve the uniformity of application of the water. It includes grading or shaping the surface to any desired slope as well as the formation of an actual horizontal plane.

Generally the reshaping is done to provide uniform grades or to reduce grade in the direction of irrigation or at right angles to it. Sometimes the grade of a field is increased or grading was done so the direction of planting could be changed. Land preparation in humid areas is needed to provide surface drainage and to achieve more even penetration of irrigation water and rain.

Because of differences in soils, slopes, or the farmer's wishes, not all fields are given smooth surfaces. Land preparation may consist only of removing a part of the high spots and filling a part of the low places. It may bring only a minor improvement in irrigation efficiency. Or it may be possible to reshape a field to the extent that beneficial use can be made of all the irrigation water and much of the rainfall.

Many irrigation workers in the Southwestern States have used a classification of types of land preparation. It is based on the effectiveness of different forms of land surfaces in improving the uniform application of water.

Six types are classified, starting with rough grading (type 1), then variable grades in all directions (type 2), up through uniform irrigation grade with side slope (type 3), level transversely with a variable irrigation grade (type 4), and with a uniform grade (type 5), and finally to exactly level in all directions (type 6). The first three types permit side slope. The others require that the land be exactly level at right angles to the direction of irrigation. The classification has proved to be useful, and something like it would be of value in all irrigated areas.

If we acknowledge that there are different types or degrees of efficiency in land preparation, we recognize that the farmer or land operator must make a choice of type when he undertakes land leveling. We say generally that the highest type of land leveling suitable to a field should be adopted, but there are situations in which something less will be satisfactory and more practical.

The land slopes, kind and depth of the soils, climate, crops to be grown, water supply for each field, economic considerations, and the farmer's preferences all have to be evaluated in designing any job of land preparation.

If the land is very rolling, steep, and irregular and the soils are shallow, it may not be possible to shape the surface to uniform slopes on good irrigation grades. Successful irrigation farming can be practiced on land of steep and nonuniform slopes, but that land should be kept in pasture as much of the time as possible in order to prevent severe soil erosion.

The development of a uniform grade only in the direction of irrigation often may be the highest practical type of land leveling. That is especially true of fields that have little cross slope, where the crops will always be irrigated by the furrows or corrugations. In orchards especially, this type of leveling is satisfactory.

Some extremely irregular fields or irregular fields with shallow soils will not permit use of a higher order of land preparation. Only a study of the cuts that will be required for better leveling can determine this, but often they will

Wells and Pumps for Irrigated Lands

In much of the arid and semiarid regions of the United States, the water from streams is completely utilized for irrigation or, if surplus water is still available, the cost of bringing it to the land is too high. In those places, therefore, pumping from the great reservoir of water in the ground is the only source of additional water for irrigation.

Factors to be considered in developing successful irrigation enterprises by pumping from wells are the supply of ground water, the land, the well, the pump and accessories, the crops, and the markets.

First is the water supply. If it is inadequate or if the quality is unsatisfactory there is no need to consider the other factors.

Next in importance is the land. It must be fertile. The topography must be suitable for irrigation.

A supply of adequate and suitable ground water usually is harder to find than land that is suitable for farming. Water exists beneath the surface of the ground in most arid and semiarid regions, but conditions often are not favorable for utilizing it to irrigate crops. Sometimes it is so far down that the cost of pumping is too great. Or the formation in which the water occurs is so tight that it does not yield water readily or is so limited in extent that the supply would soon be exhausted. Or the rate of recharge of the ground water reservoir is too small to justify extensive development of the area. Or the supply may contain too much salt.

Alluvial deposits containing thick layers of water-bearing sand and gravel are most favorable for obtaining a good water supply. Broad alluvial valleys, traversed by rivers or irrigated by a network of canals, are ideal sites. The seepage from the rivers and canals and the deep percolation loss from irrigation nearly always assure adequate recharge of the ground-water reservoir. In such valleys the water table usually is quite close to the surface, an important aspect from the standpoint of pumping costs.

No hard-and-fast rules can be laid down as to the depth to water beyond which pumping is no longer feasible for irrigation. It depends primarily on the value of the crops produced. In California and Texas, where fruits, cotton, and winter vegetables are grown, lifts of 400 to 500 feet and more are common, but in other areas where general farm crops are grown, 100 feet is probably the maximum, except under special conditions. If sprinklers are used, the total pumping lifts can be higher because the amount of water required usually is less.

The water need not be potable, but it must not contain high concentrations of salts injurious to plants or soil. Water of doubtful quality should be tested to determine which alkalies are present and the percentage of each.

Soil Moisture in Relation to Plant Growth

Growing plants transpire enormous quantities of water which they take from the soil. One cornfield in Iowa transpires enough water during a season to cover the field to a depth of 12 or 16 inches. The production of 1 ton of dry alfalfa hay on the Great Plains may involve the transpiration of 700 tons of water--more or less, depending on the evaporating power of the atmosphere. At a temperature of 75° F. and a relative humidity of 50 percent, a tensional force of approximately 1,000 atmospheres would have to be applied to water to stop evaporation.

Plants lose water continuously. The lowest loss is at night and the highest at midday. But often the soil water is not replenished by rain or irrigation over periods of weeks or months. Hence the soil acts as a moisture reservoir for the plants.

To a Colorado wheat grower, who may harvest 50 bushels an acre or nothing, according to the status of the moisture reservoir in his soil in a given season, it would be diffidult to overemphasize the importance of soil moisture in plant growth.

The capacity of the soil moisture reservoir is limited by the field capacity (upper limit) and the permanent wilting percentage (lower limit) of the soil in the effective root zone of a crop. Field capacity is the moisture percentage of a soil, expressed on dry-weight basis, in the field 2 or 3 days after a thorough wetting of the soil profile by rain or irrigation water. Permanent wilting percentage is the moisture percentage of soil at which plants wilt and fail to recover turgidity. It is usually determined by growing dwarf sunflower plants in small containers of the soil under examination. The moisture held by the soil against a displacing force of 15 atmospheres (221 pounds a square inch) is a good estimate of the permanent wilting percentage.

There is a wide disparity between the value of 1,000 atmospheres associated with the evaporating power of the air on a warm, dry day and the 15 atmospheres of soil moisture tension associated with the wilting of plants. Rate of entry of water into the roots is impaired by the prevalence of only a few atmospheres of soil moisture stress, even though the plant can withstand a great drying force at the leaf surface.

The permanent wilting percentage of soils may vary from 3 percent for a coarse sandy soil to 23 percent for a fine clay. Comparable figures for the range in field capacity are 8 and 40 percent.

F. J. Veihmeyer and A. H. Hendrickson, of the California Agricultural Experiment Station, have conducted extensive experiments demonstrating the usefulness of these two soil moisture constants in irrigation practice. They designate the moisture held by a soil in the range between field capacity and permanent wilting percentage as the available range. Thus the moisture reservoir constitutes the water in the available range held by the mass of soil in the active root zone.

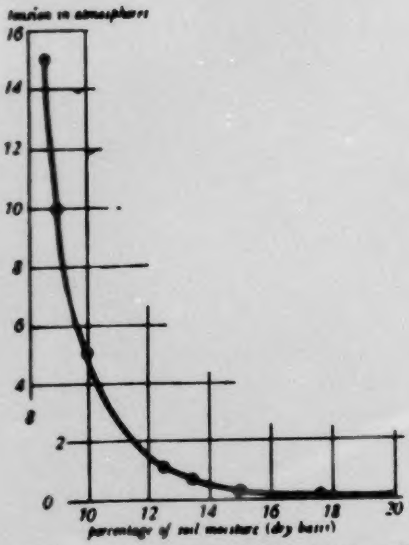
Let us examine the amount of water that may be available in a unit volume of soil, say, 1 cubic foot. A mineral soil is made up of three major components, air, water, and mineral particles. One cubic foot in the dry state will weigh from 65 pounds for clays to 110 pounds for sands. Soil particles have an average density of 2.65, and a cubic foot of soil minerals would weigh 165 pounds. Thus, as much as 60 percent of the volume of a clay soil may be voids filled with air and water. In coarse sands it may be as low as 30 percent.

It is essential for most plants that the voids be only partially filled with water in order to provide necessary aeration.

Plants vary markedly as to rooting habit under favorable soil conditions. Roots of lettuce and spinach penetrate only 12 to 15 inches; those of potatoes and peas, about 2 feet; tomatoes and tobacco, 3 feet; field corn and asparagus, 4 feet; and alfalfa and grapes, down to 8 or 10 feet or more. Potatoes growing in a loam that can hold 1.5 inches of available water per foot of depth would have a total moisture reservoir of 3 inches of water--enough for a vigorously growing potato crop for about 1 to 3 weeks, depending on the evaporation rate.

There is evidence that the water in the available range of a soil is held equally available to crop plants, even though water at the upper limit, field capacity, is withheld from the plant roots by a tensional force of about only 1.5 pounds a square inch; whereas water at the lower limit, permanent wilting percentage, is withheld by a tensional force of about 200 pounds a square inch. Those values constitute a wide range in tensional force. Why, then, do we find evidence that insofar as plant growth is concerned water is equally available between those limits?

The relationship between soil moisture tension and moisture content provides an answer:



This chart shows the relationship between soil moisture content and tension in Panoche loam.

When To Irrigate And How Much Water To Apply

Plant roots will not grow in dry soil. Water from rain or irrigation that fails to moisten the full depth of dry soil will encourage shallow rooting, which often is undesirable. If only the upper part of the dry soil is wetted, losses by evaporation are increased and plant growth is retarded more quickly than if the entire root zone is moistened.

Too little water to moisten the root zone and too much water both produce undesirable effects on crops and waste water that may be needed for other purposes or in other places. It is therefore highly desirable to apply enough water to moisten the root zone without excessive loss by deep percolation, except when you have to leach the soil of undesirable salts.

Water moving into dry soil forms a distinct wetting front. Dry soil is slower to wet than moist soil and the wetting front is sharper in the drier soils. Consequently, when a limited amount of water is applied to dry soil, the water will be distributed unevenly. The surface soil becomes moist, but the subsoil remains dry.

Water will continue to move from the moist soil to the dry soil for a long time, but most of the movement will be completed after a day or two. The amount of water retained after 1 or 2 days of drainage, expressed as a percentage of the dry soil by weight or volume, is known as the field capacity of the soil. It is not an exact figure, because the movement may not cease. The degree of dryness before application of water and structure or texture also cause changes in the amount of water the soil retains.

Work is required to remove water retained by the soil. Curves that relate the amounts of water retained by a soil at different moisture contents and the work required at each level to remove a unit of water are called moisture-release curves. More work is required as the soil becomes drier. Because a given force acting over a given distance produces work, the force or pressure per unit area is used as a measure of the retention of water by soil. This force of retention is called moisture tension.

When measured in the field, water is retained at about 1.5 pounds per square inch, or one-tenth atmosphere of tension, when the soil is at field capacity. When disturbed samples are measured in the laboratory, the same moisture content is obtained at about 5 pounds per square inch, or one-third atmosphere. The difference is probably a result of changing outflow boundaries; the flow of water from disturbed soil to a membrane or ceramic plate is vastly different from the flow in undisturbed soil.

Although the plant roots take water freely from soils at field capacity, the work required to remove the water becomes progressively greater as the soil becomes drier and the forces of retention increase. Different soils release different amounts of waterfor each increment of work. Whenever the soil moisture is reduced to a point that a large change in work is required to remove only small amounts of water, the plant will soon suffer from moisture deficiency. Water should be applied before that point is reached by most of the soil in the root zone or plant growth is checked.

Soils in which the moisture content is depleted until plants wilt and fail to recover when placed in a moist atmosphere in the dark are said to be at the permanent wilting point. This represents the lower limit of available moisture. Like field capacity, the wilting point cannot be determined exactly, and it cannot be found for some soils, particularly salted soils. For many soils the permanent wilting point lies within the range of moisture tension from 10 to 20 atmospheres. The percentage moisture at 15 atmospheres is considered frequently to be equivalent to the permanent wilting point. Approximately 45 times as much work is required to remove moisture at the wilting point as is needed at field capacity. Although all the water from field capacity to permanent wilting point is considered to be available to plants, they wilt temporarily long before that point is reached.

The soil may be considered roughly as a reservoir for soil moisture, with the upper limit at a moisture content corresponding to field capacity, and the lower limit at the permanent wilting percentage. Roots correspond to a pump with many inlets that may penetrate deeper into the reservoir as the crop grows. As the soil gets drier, more energy is required to pump the water out, for it is getting lower in the reservoir. A distinct and important difference exists at this point between a true reservoir and the soil. The water in a reservoir is free to run to the pump inlet and moves more rapidly than the pump can extract it. Water in the soil is not free to move to the plant roots, and it may move much more slowly than the roots and plant can remove it. Then the plants may wilt, only to recover when the demand is reduced.

Coarse soils transmit water faster than fine soils when the water is retained at low tensions. At higher tensions, however, water movement is more rapid in fine soils.

Frequency of irrigation and amount of water to be applied are affected by the fertility of soils. Unless enough nutrients are available to the plant to produce maximum growth at all times, nothing will be gained by keeping moisture available at low tensions. Nitrogen may accumulate in the soil during periods of slow growth when moisture tension is high; then, when water is supplied, the crop may use up the accumulated nitrogen rapidly. If moisture is kept constantly at low tensions, so that it never limits growth, the nitrogen may still become available at about the same rate and crop yield may be about the same. The plants might show nitrogen-deficiency symptoms in one instance but not in the other. The most desirable frequency of irrigation can have maximum benefit to the crop only if a supply of readily available nitrogen is present in the soil.

Sometimes maturity of a crop is delayed by periods of low moisture during its vegetative stage. If sweet corn is kept moist and is fertilized with large amounts of nitrogen and has enough of the other nutrients, it will mature as much as 2 weeks earlier than corn with limited fertilization that also is constantly moist. If moisture tension increases just a little during the early, fast vegetative stage of growth, the early maturity is lost and yields are lowered.

Phosphorus is taken up by plants more easily from moist than from dry soils. Because phosphorus does not move appreciably in the soil, it is taken up from the same relative depth at which it is applied. A common practice is to apply fertilizer near the surface. If so, and if phosphorus is the limiting element, light, frequent irrigations may produce growth far out of proportion to their value in ideal conditions.

Crops respond differently to moisture tension at different stages of growth. When vegetative growth is rapid, plants react quickly to moisture stress. If the soil becomes dry at this time, new leaves do not develop fully, and a general reduction in succulence follows. When water again becomes available, rapid growth may be resumed, but the small leaves and stems produced under high moisture stress never become fully enlarged, and the plant seldom catches up with the plants that were not subjected to the stress. Potatoes are sensitive to soil moisture from planting until the tubers are fully formed. Sugar beets are most sensitive in the seedling stage and (like most other crops) continue sensitive until the growth rate is retarded by maturity. Field corn requires water at low tensions from seeding to hard-dough stage for maximum growth and yield. It is particularly sensitive to moisture stress at silking time and shortly thereafter. Small grains are similar to corn. Very little difference in yield can be demonstrated by moisture variations during the ripening period.

Tobacco transplants are resistant to moisture stress for relatively long periods of moisture deficiency, but when enough water is once supplied to initiate rapid vegetative growth, a continuance of water at low tension is required to develop the crop properly.

Peaches are particularly sensitive during the period of rapid enlargement of the fruit. Apples enlarge at an almost uniform rate and need a steady supply of readily available moisture.

Maintenance of low moisture stress assures a maximum of vegetative growth but does not always assure the quality and quantity of the marketable crop when fruits and seeds are harvested. The quality of apples and pears may be improved by restricting the supply of irrigation water during the ripening period. Water is then required again near picking time to prevent desiccation and injury to next season's fruit buds during the winter.

Truck crops need to be grown at high moisture levels to develop the succulence and tenderness that the market demands. These crops respond well to light, frequent irrigations because they are relatively shallow-rooted. Deep-rooted crops, such as alfalfa and orchards, may produce well with heavy, infrequent irrigations, and many annual crops, such as corn, cereal grains, and sugar beets, are intermediate.

Young plants that only partly cover the ground have very small root systems. Such plants need water just as much as when they are older. They should not be allowed to suffer for water in the mistaken belief that the root system thereby will be forced downward into deep soil. Plant roots grow deeper in soils that are kept moist, but not wet, during the early stage of growth. It is true that the root system is capable of rapid growth at this stage, but the growth of both roots and shoots is reduced during any period when moisture is deficient in that portion of the soil already occupied by roots and the plant that so suffers generally is permanently retarded by the adverse condition. Sometimes the retarded plants may be allowed to grow for a longer period than the other plants and produce an equal yield, but usually that is not the case.

Water should be applied for a long enough period to get sufficient water in the soil to moisten the dry soil without appreciable amounts moving into the moist soil below. In order to bring this about, water must be turned off shortly before the entire root zone becomes wet. Subsequent drainage for the next 24 hours will be sufficient to moisten the balance of the soil in the root zone and deep percolation will not be excessive.

The application of water should be slow enough to avoid erosion and water wastage through runoff. Many soils take water at rates between one-fourth inch and 1 inch per hour. High infiltration rates are favorable to the use of sprinkler irrigation systems. In furrow irrigation, high infiltration causes more water to enter the soil near the head of the field before the area is covered and, in extreme cases, results in excessive penetration there while irrigation at the lower end is still deficient.

The times when irrigation water should be applied can be determined despite the many variables. To do it most accurately you must know the depth of soil from which moisture is being extracted and the moisture tensions throughout that depth.

You can determine the depth from which water is being extracted by using one of the several methods of measuring soil moisture.

If determinations are made at several depths and at regular intervals, the varying rates at which moisture is being removed from different depths can be observed. If no active plant roots are present, the rate of moisture removal is slow. Moisture tensions may be determined at the same time as the depth of rooting. The instruments indicate tension directly or are otherwise calibrated to register tension or moisture content which can be converted to tension by using moisture-release curves.

Available water will still be present in the root zone in appreciable quantities when the time to irrigate arrives, because of the way water is removed by crops. Plants draw a disproportionate amount from the upper soil where their concentration of roots is greatest; evaporation also removes water most readily from the surface soil; thus when 60 percent of the available water has been removed from the upper quarter of the root zone, exhaustion of the entire root zone may be less than 30 percent. Relative amounts will vary with crops, weather and soil conditions, but the wilting point is reached first in the upper soil. Irrigation is needed when only a part of the root system is restricted in supplying water to stems and leaves.

Best results with irrigation are obtained for most crops if water is applied before the average tension in the zone of rapid moisture removal goes above 4 atmospheres and if irrigation is withheld whenever the tension is below one-half of 1 atmosphere. Tension-indicating meters or resistance units for measuring soil moisture may be placed at various depths and read periodically to indicate these moisture conditions that represent a range of about 30 percent to 80 percent of the total water retained between field capacity and the permanent wilting percentage on many soils.

A commonly accepted generalization calls for irrigation when 60 percent of the available water in the root zone is depleted. If water additions are confined solely to irrigation, fields may be irrigated in sequence as they approach that level. Rainfall at any time before or during the growing season, however, may result in approximately the same moisture level over the entire area. Irrigation may be needed later.

If the farmer has a large number of fields and irrigates one or more of them a day, the moisture level in the last tract may be at or near the wilting point by the time he gets to it. He should start soon enough to arrive at the last field before its available water is completely exhausted. This is the reason for irrigating in a range of from 30 percent to 80 percent depletion. If this range represents 3 inches of available water in the root zone and consumptive use is 0.3 inches a day, he has about 10 days to complete his irrigation. Soil moisture will seldom be reduced to the permanent wilting point before irrigation is applied if some good method is used to indicate in advance the water status of the soil.

Very sandy soil may have a capacity of less than 1 inch of available water per foot depth of soil. Clays and organic soils may retain 2.5 inches or more. The range for most soils lies between 1 and 2 inches for each foot of depth. To express these figures as volume percentages, the depth of water retained is divided by the corresponding depth of soil (in inches) and multiplied by 100.

The amount of water to apply to replenish the moisture in any depth interval of soil can be calculated by subtracting the amount of available water that is present from that which the soil will hold without deep percolation loss. If this value is stated as a volume percentage decimal, it need only be multiplied by the depth of soil in the sampling interval to convert it to a depth of water per acre. If the depth interval is 6 inches and the volume percentage is 20, then the amount needed to restore that 6-inch interval is 1.2 inches. Any additional water will be lost by percolation and will leach soil nutrients.

The Irrigation and Culture of Rice

Upland rice, which is not irrigated, and paddy, or irrigated, rice require different varieties and different cultural methods.

All of the commercial rice in the United States is grown under controlled irrigation. Several systems of controlled or uncontrolled irrigation are used in various countries to supply the water needed for the development of the rice plants.

Upland rice is grown in areas where rainfall is heavy during the growing season. Much of the rice grown in Central America and South America and in many countries in Asia is produced under upland conditions. Upland rice also is grown for home use in small fields, totaling fewer than 3,000 acres, in the Southeastern States.

A limited acreage of "providence" rice is grown in Louisiana and elsewhere in the Southern States. Field levees are constructed as for irrigated rice, but rainfall supplies the needed water. Fairly satisfactory yields are produced in seasons of uniformly high rainfall, but average or dry seasons mean low yields.

Floating rice is grown in southeastern Asia where streams overflow during the growing season. Some especially adapted varieties are sown before the flood season. The waters rise slowly, and the fields remain inundated for several weeks. Meanwhile the plants elongate rapidly as the depth of the water increases. The culms are weak but are supported by the water. When the water recedes, the plants lodge, but enough straight growth remains so that the panicles are off the ground and seed is produced. Rice produced in that way must be harvested by hand.

Land suited to rice usually is rather level and has a definite drainage pattern. In the Philippines and elsewhere in southeastern Asia, however, rice is grown on terraces in mountain regions, where sometimes the entire mountainside has been converted into a series of rice paddies. Spillways permit the water to flow down from one terrace to another.

In the United States the irrigation water is diverted from streams or is pumped from rivers, bayous, wells, lakes, or reservoirs. The water is delivered into field levees, which are built on the contour and keep the field submerged at a fairly uniform depth.

Rice growing in the United States started in the 17th century near Charleston, S. C. Rice soon became an important crop along the tidal streams in the South Atlantic coastal area. The fields along the streams were divided by drainage ditches and levees into plots of about the same level. The levees were constructed from the earth taken from the ditches. The small fields were next to canals, which carried the water from streams. The canals also connected small streams, formed dividing lines between plantations, and provided for barge transportation during planting and harvest. Floodgates, located above the salt-water line in the streams, controlled the flow of water into the canal. The gates were placed so that water flowed into the canals at high tide and was shut off at ebb tide. The gates could be opened at low tide to drain the fields.

New settlers, coming in after 1865, attempted to grow rice on the prairie in southwestern Louisiana.

They found that rice grew very well there, and that the sluggish streams, called bayous, provided plenty of water for irrigation. The problem was to get the water to the higher lands. The first attempt was to dam up small drainage areas and collect water during the winter. The water was pumped to the field by small pumps driven by steam engines. These systems were improved, until in 1894 the first large irrigation plant was established on Bayou Plaquemine, about 2 miles from Crowley, La. It first used a vacuum-type pump, which failed in midsummer. The next year a centrifugal pump was installed, but it did not have enough capacity to deliver the water needed for the entire acreage. A larger centrifugal pump, installed in 1896, delivered 5,000 gallons of water a minute, enough for the planted acreage. Many pumping plants were installed on the streams in southwestern Louisiana and southeastern Texas the next few years. Some pumping plants in operation in 1901 delivered up to 45,000 gallons a minute.

The water requirement for rice is rather high, because the fields are submerged for 3 to 5 months.

In California 3 to 8 feet are needed each season. The requirement in Arkansas and Louisiana is 1.5 to 3 feet. The amount of irrigation water required is least in places where the subsoils are relatively impermeable and the seasonal rainfall is high. The normally abundant rainfall cuts the pumping requirements in the rice sections of Arkansas, Louisiana, and Texas, but unusually heavy rainfall may cause breaks in the levees and serious losses of water.

More than 40 percent of the 1953 rice acreage in the United States was irrigated from wells. About 90 percent of the 485,000 rice acres in Arkansas, 40 percent of the 604,000 acres in Louisiana, and 20 percent of the 573,000 acres in Texas, 10 percent of the 394,000 acres in California, and most of the 75,000 acres in Mississippi were irrigated from wells.

Pumping from bayous supplies most of the surface water in Louisiana and Texas. Diversion from large streams is the main source of water in California. The main surface water supply in Arkansas is from excess rainfall stored in reservoirs. These reservoirs vary in size from 20 acres to more than 4,000 acres and are filled during periods of high runoff.

Heavy, concentrated pumping has seriously lowered the ground water level in some parts of Arkansas, but other sources of irrigation water are being developed. The recharge of ground water through wells has been considered.

Diesel engines came into common use for pumping water after 1919.

Convenience, low labor requirements, and reasonable initial and operating costs have since caused a shift to electric power for irrigating rice. About 1,800 irrigation installations, nearly 50 percent of the total, were powered by electricity in Arkansas in 1955. In Louisiana, of a total of 1,061 wells, 450 were powered by diesel engines, 212 by natural gas, 105 by electric motors, and the remainder by other units.

The efficiency of the pumps has improved rapidly, so that outlays for electricity have dropped. Pump bowls ordinarily had an efficiency of about 20 to 40 percent in 1915. Modern pump bowls of suitable design have efficiencies of about 83 percent.

Costs of electric power for irrigating rice in Arkansas ranged from 4.68 to 11.24 dollars an acre in 1954. Fixed or overhead costs averaged about 3.75 dollars an acre. The electric rates for rice irrigation are lowest for pumps that operate continuously during the season, but it may be advantageous to pay slightly higher rates in order to have a larger flow of water during some periods and to reduce the time expended in irrigating. A flow of 5 gallons a minute an acre delivers the average of 22 acre-inches required in slightly more than 80 days, while 7.5 gallons requires a little less than 60 days. The average well flow on Arkansas rice farms has been estimated at about 7.1 gallons a minute an acre. Farm experience thus indicates a preference for more than the minimum.

The water is conveyed from the pumps, streams, or reservoirs in canals, from which it is diverted into laterals, field ditches, and finally the field checks, or levees. Those structures should be located by a competent engineer and be of proper size to provide water when and where it is needed.

When the rainfall is below normal in the gulf coast of Louisiana and Texas, the water level in the streams that supply irrigation water often is so low that brackish water encroaches from the Gulf. The concentration of chloride salts may become so high that the yield and quality of the rice is reduced or the crop ruined.

Water that contains more than 35 grains of salt a gallon (600 parts per million) should not be used to irrigate young rice if the soil is dry and if the water is to remain on the field. Rice watered continuously with water containing 35 and 75 grains of salt a gallon (600 and 1,300 parts per million) was reduced in yield about 25 and 70 percent, respectively, and the rice was of lower quality than when water containing 25 grains a gallon was used. The rice plant can tolerate higher concentrations of salt, in the later stages of growth, although very high concentrations may kill the plants or make them sterile. The Blue Rose variety is more tolerant to salt than some other varieties and has made satisfactory yields when the water contains salt concentrations of 75, 150, 200, and 250 grains a gallon in the tillering, jointing, booting, and heading stage, respectively. Some of the newer varieties probably would be damaged seriously by those amounts of salt.

If a field has been watered with fresh water and the supply is then replenished with salt water, the damage will be less than if the salt water is put on dry soil. The reason is that the salt is more concentrated in the dry soil and more of it moves into the root zone, whence it is taken up by the plants. Rice grown on clay soils may not be injured by salt water to the same extent as on lighter soils, because less water is used and less is lost by seepage.

About 3 tons an acre of salt are added when water containing 50 grains of salt a gallon is used for the whole growing season. The accumulations of salt over the years may deflocculate the soil, so that stickiness, compactness, and impermeability increase. The deflocculated soil is hard to cultivate and produces low yields.

Well water, used to irrigate a large part of the rice acreage in Louisiana and Arkansas, usually is low in chlorides. In the lower basin of the Vermillion River in Louisiana, however, salt water encroaches on the Chicot Reservoir when the river is intruded by salty water.

Water from shallow wells sunk into Quaternay beds in Arkansas contains 75 parts per million of calcium and 22 parts per million of magnesium. Soils that have been irrigated for many years with this well water have increased in pH ratio from about 5.0 up to as high as 8.0. That change from a highly acid to a highly alkaline reaction is due to the annual addition of about 1,500 pounds an acre of limestone equivalent. The increase in available calcium and magnesium lowered the availability of phosphorus in the soil. If a new source of water is obtained that is low in dissolved minerals, those changes may be reversed.

Rice has been grown in order to reclaim saline or alkali lands in California. It is successful when the water is appreciably lower in dissolved minerals than is the soil, the soil is relatively permeable, and drainage is adequate. Crops that are not salt-tolerant can be grown on the alkali soils after 2 or 3 years of rice.

The temperature of the irrigation water is important. The temperature may be too low early in the season and too high late in the season for maximum emergence of rice sown in the water. Germination is retarded when the temperature of the water is below 70° F. Roots develop poorly when the temperature is above 85°, perhaps because of the low oxygen content of warm water. The temperature of the water from shallow wells in Arkansas and from streams in California is usually 65° F. or lower. When such cool water goes directly into the field, the rice growing near the water inlet usually is retarded. Such "cold water" rice may ripen 7 to 10 days later than the rice in the rest of the field, and the difference interferes with harvesting. The way to avoid that condition is to hold the water in a warming basin or to have several inlets to the field. The water from deep wells in Arkansas and from the streams, lakes, and reservoirs in the South usually is warm enough.

Water is delivered usually to the highest point in the field by canals or pumps. It passes into successively lower paddies through openings or metal checks in the levees. Metal checks provide permanent control of the maximum height of water in each paddy. Field levees must be properly spaced on the contour to provide uniform irrigation and complete drainage. Levees are spaced at a difference of about two-tenths of a foot elevation between adjacent levees. Smoothing the land before surveying results in more accurate surveying, more uniform irrigation, and better drainage.

Either levee disks or pusher-type machines form levees with sloping sides and high enough to hold water 4 to 6 inches deep on the subfields or paddies without overflowing into the next lower paddy. Low, sloping levees reduce production costs because they can be seeded and thus produce considerable rice while reducing weed growth.

Two general methods of seeding and irrigating rice are practiced in the United States. One is to drill the seed in the soil; submergence follows. The other is to broadcast the seed in the water.

Most of the rice in the Southern States is drilled or is sown with an endgate seeder and covered with a disk or harrow. The soil is then irrigated lightly if moisture is needed for germination and growth of seedlings. Later the soil is submerged when the plants are 6 to 8 inches tall.

The seedbed is prepared by plowing with a moldboard or disk plow in the fall, winter, or early spring, followed by disking and harrowing, and sometimes the use of a heavy plank drag to break the clods. Heavy soils, such as Sharkey or Beaumont clay, usually are dry by the time the land has been prepared and seeded so that it becomes necessary to irrigate to germinate the seed unless rain comes soon after seeding. The field must be drained after the early irrigation, because rice seed that is covered with an inch or more of soil will not germinate in standing water. This practice, however, also provides ideal conditions for the germination and growth of weedy grasses.

Experiments started in 1914 on new rice lands in California showed that the best yields were obtained when the land was submerged to a depth of 6 to 8 inches about 30 days after the rice seedlings emerged. This method, however, favored the invasion and increase of weedy grasses, particularly barnyard grass (Echinochloa species), and therefore was not suited to old rice lands. Experiments in Arkansas demonstrated that a heavy infestation of grass reduces the yield of the rice by 50 percent or more. Water-seeding methods were developed to control the weedy grasses.

The seeding of rice in water was started in California as a way to control barnyard grass. Low spots covered with water when a field was being drilled often were sown by hand broadcasting, and such spots were observed to be relatively free from barnyard grass. Experiments in seeding rice in the water about 6 inches deep demonstrated that many grasses could be controlled in that way, and good stands of rice and high yields could be obtained. The rice germinates and emerges through 6 inches of water, whereas the grasses seldom get to the surface of the water. At first the rice was sown with a broadcast seeder. Broadcasting in water with an endgate seeder stirs up mud, which makes it hard for the driver to follow a straight line. The airplane is more satisfactory for sowing submerged land. The airplane operator is guided by flagmen, one at each end of the field, who pace off the distance (about 30 feet) that the plane can sow in one trip across the field.

Airplane seeding was attempted first near Merced, California, in 1929, for reseeding a field in which the rice had been destroyed by mud hens. A fair stand of rice and a satisfactory yield were obtained. Several California growers seeded their rice with an airplane in 1930. Now airplane seeding is the common practice among growers in California. Experiments with water seeding in Arkansas and other Southern States developed modifications, which were adapted to the other areas.

The prevailing method of growing rice in California is to plow the land in early spring to a depth of 4 to 6 inches and allow the soil to dry for 7 to 10 days. A satisfactory seedbed can then be prepared by harrowing twice and floating once with a heavy plank drag. The field levees are then put up, the floodgates put in place, and the field flooded to a depth of about 6 inches. Seed that has been soaked for 36 to 48 hours is then sown with an airplane at the rate of 135 pounds of seed an acre. The field is kept submerged to a depth of 5 to 7 inches until the rice is ready to drain before harvest. Preparing the seedbed when the soil is dry gives better control of some of the aquatic weeds and grasses that cannot be controlled by flooding and retards the growth of algae (green scum) on the surface of the water.

In the water-seeding method in Arkansas, the land usually is plowed in winter, and the seedbed is prepared by disking 2 or 3 times and then harrowing. Frequently the soil also is tilled to a depth of about 8 inches with a field cultivator to provide space for the application of cool irrigation water that contains oxygen, which is necessary for early root development. The water below the surface of the soil remains cool and retains considerable oxygen, whereas the surface water is warmed by the sun, and much of the oxygen escapes.

The levees are completed after the soil is worked with the field cultivator, and the field is then cultivated with a springtooth harrow, which leaves shallow furrows and ridges that prevent drifting of the seed. The floodgates are then put in, the field submerged to a depth of 4 to 6 inches, and the rice sown from an airplane. Seeding is done as promptly as possible, as poor stands usually are obtained when the water has been on the field longer than about 4 days before seeding. The seeding rate is 100 to 110 pounds of dry seed an acre. The water is usually drained after 5 to 6 weeks for the control of the rice water-weevil and to provide dry soil for top dressing with fertilizer.

The water-seeding method as practiced on heavy clay soils in Texas and other Southern States consists of plowing and disking the land to kill vegetation, but the surface is left rough. The levees are then put up and the field is irrigated enough barely to cover the land. The flooded field is then cultivated with a light disk or heavy spike tooth harrow. The soaked seed is sown immediately from an airplane. Sometimes a shallow flood is left, but usually the excess water is drained off the field after seeding and the seeds are covered with a thin film of mud. Germination of the presoaked seed is rapid. As soon as the seedlings emerge, a shallow flood of water is added to fields that were drained after sowing. The depth of water is increased gradually up to 5 to 7 inches as the seedlings elongate. The water may be drained 1 or 2 times during the growing season to control insects or to apply fertilizer.

Correct timing of irrigation and drainage may help to control certain insects. The root maggot has reduced yields up to 29 percent in some areas, and increases of 11 to 27 percent in yeild have been obtained by draining the field when heavy pruning of the rice roots by the maggots is evident. That usually occurs about 17 to 28 days after the field is first submerged. The practice, however, makes an ideal breeding place for rice-field mosquitoes (Psorophora confinnis and P. discolor). They lay their eggs on the soil from which water has been drained. The eggs hatch when the soil is again submerged. The southern corn rootworm, chinch bugs, sugarcane beetles, and the southern grass worm, which often are serious pests in some places, often can be controlled somewhat by submerging the field when seedlings are attacked or by holding the water on the field as long as possible when the rice is attacked as it is nearing maturity.

Several diseases of rice can be controlled or the losses from them can be reduced by using the correct irrigation methods. Straighthead is a nonparasitic disorder characterized by failure to set seed, usually accompanied by a distortion of the palea and the glumes. Straighthead sometimes is destructive in the Southern States on soils high in organic content. It occurs most frequently on sandy, loamy, or mixed soils but rarely on clay soils. Effective control is obtained by draining the field just before the panicle bud forms--usually 6 to 8 weeks after emergence, depending upon length of growing season of the variety. The field is flooded again as soon as the soil is dry.

Stem rot, a fungus disease, first appears in midsummer as small, discolored areas on the sheaths of the rice stem near the water line. The most satisfactory method of control is to drain the water from infected fields before the infection reaches the culm. Water should then be added from time to time to keep the soil saturated but not submerged. Such treatment may result in reduced losses from lodging, but a slight reduction in yield is usual where infection is light. Such irrigation should not be practiced unless infection is heavy.

Blast, caused by the fungus *Piricularia oryzae*, has caused losses in yield in the Southern States from time to time. Usually the most obvious and damaging phase of the disease is the infection of culms and panicles after the plants have headed. Infection also occurs in the seedling stage and causes a reduction in stand before the field is submerged, but then injury may be reduced by submergence of the land as soon as the leaf spots become evident.

Growing 100-Bushel Corn With Irrigation

Corn cannot be grown profitably without irrigation in the arid sections of the West. Irrigation changes corn from a marginal to a profitable crop in semiarid areas. It removes the everpresent hazard of drought in the subhumid area and the humid East.

Corn yields greater than 150 bushels an acre have been obtained in experiments under irrigation at several places in dry sections of the West. Such yields were obtained only by the use of the best combination of practices, but farmers in those areas can expect to improve yields by adopting similar practices.

Benefits from irrigating corn vary from year to year in the subhumid and humid sections. Experiments at the Redfield Development Farm in South Dakota showed increases in yield due to irrigation of 117 and 27 bushels an acre.

DRYLAND FARMING

Farming Where Rainfall Is 8-20 Inches A Year

Dryland farming no longer means simply farming in a region of low rainfall. Rather, it has come to refer to a fairly well established system of managing crops and soils that is adapted to semiarid or dry climates.

Such a climate exists in various parts of the world, including parts of all the Western States, notably the Great Plains, the Great Basin, the Pacific Northwest, and the Central Valley in California.

The total precipitation in the dry-farming areas generally is low, about 20 inches down to 8 inches annually.

Scant rainfall, though, is only one aspect. The average temperature in the Northern States is much lower than in the Southwestern States. A given amount of precipitation therefore is much more effective in the North than in the South. The distribution of the precipitation through the year also is important. The limited precipitation in parts of the Pacific Northwest comes mainly in winter, when evaporation is low. So the rain penetrates deeper into the soil and subsoil than does the much higher rainfall of the Central Plains, where the moisture comes chiefly in summer. A rain of one-half inch on a hot, dry day may lose so much of the water by evaporation that only a small fraction is available to the plant. During cool weather a rain of one-half inch may penetrate the soil to the extent that much of it may be used eventually by a crop.

Wind erosion of the soil is common in most dry-farming regions, particularly in sandy areas. In many places an occasional torrential rain or a sudden heavy shower may cause considerable erosion.

Great progress has been made toward producing a great share of the Nation's food in the West, a part of which the early explorers called the Great American Desert. Livestock and small grains are the food products that can be grown to best advantage. Research has had a great effect on the progress of all limited-rainfall regions. The mechanization of farm operations has altered labor requirements and has changed the cost of production in regions where an extensive agriculture is practiced.

As the Great Plains were settled, largely during the last quarter of the 19th century, farmers drove their covered wagons westward from the humid areas of the Eastern States to those low-rainfall regions. They brought with them the methods of a humid agriculture. They also brought the seed for crops that had been found suitable for humid conditions. They soon learned that the types and varieties of crops they had used back east would not withstand the climate of the Plains: Corn was not successful in most years. The soft wheats of the East would not produce satisfactory yields in the Plains.

New methods were developed only with the coming of certain Europeans, like the German-Russians, who settled in central and western Kansas. They brought from the regions around the Black Sea varieties of hard red winter wheats that had been grown under conditions like those of the Great Plains. Since then great improvement has been made in varieties and in the methods of managing soils and crops, and greater agricultural stability has come to all dry-farming localities.

The improvement in methods came from two main directions: The hard earned experience of farmers in the new and demanding environment and the work of experiment stations.

The experiment stations for studing dryland problems were authorized by the Congress in 1905. Within the next decade about 25 stations were established in the dry-farming areas.

Some stations gave attention to livestock. Some studied horticulture, landscape gardening, and forestry so as to improve living conditions on the Plains. But their work was devoted mainly to problems of soils and crops--testing and comparing methods of production, conserving soil moisture, and, much later, conserving the soil itself.

Failure to recognize the capability of the land brought about a great number of failures in the dryland areas.

Many of the critical problems there arose because of plowing up grassland that is unsuited for cropping in places of limited rainfall. Particularly in the southern part are the soils hazardous--very sandy or shallow. An estimated 7 to 8 million acres of that kind were cultivated in the Southern Great Plains in 1954. Even moderately sandy and moderately deep soils in the southern dryland regions are hard to protect against wind damage if they are placed under cultivation. It is advisable to cultivate them only occasionally. Grass should cover the land at least half the time.

Steepness of slope adds to the complexity of the erosion problem. Cultivated lands on 2-percent to 5-percent slopes in the 17-inch rainfall belt of the Southern Plains tend to be damaged 2½ times as fast as similar land that is nearly level. When rain totals 20 inches, the rate of erosion becomes about 16 times faster.

The slope of a piece of land should therefore be given full consideration in deciding whether it is suitable for long-time cultivation.

Livestock men were the first settlers in the Plains and other dryland areas of the United States. Up to that time the Indians had obtained much of their food from the great herds of buffalo. Cattle replaced the buffalo, and the cattlemen virtually took over the Plains as a grazing region.

As settlements increased and towns grew, the demand for farmland increased. The cattlemen were thus gradually pushed back until all the land that could be plowed easily had been broken. The open range disappeared and barbed wire enclosed the plowed fields and pastures. Mostly only rough land was left for grazing, which farmers used for small herds, which got some feed from crops grown on the plowed land.

This livestock system has come to be one of the stabilizing types of dryland farming. The man who lives on the land and farms on a year-round basis usually gets along better and is more sure of a good living if he has some livestock.

He can then work out his cropping system so as to make use of land for grazing and also produce grain and rough feed for winter. His main precaution is to adjust the number of livestock to the feed and pasture he will probably have in unfavorable years. He then will be able to build up some reserve supply of feed for the poor years, or he may have some for sale in good years.

The crops grown for feeding vary in different sections of the dry-farming area. Grain sorghums, sudan grass, or some type of sorghum for hay may be used in the southern part of the Plains to supplement native pasture. Some legumes, like cowpeas for feed, and pinto beans may be grown if climate is favorable. In many places wheat may be used for pasture at certain times if overgrazing and pasturing too late are avoided.

In the central and northern parts, some other crops may be used to supplement the pasture. Some corn may be produced, but sorghums are less well adapted than farther south. Barley and oats also are feed crops. Rye may be used for pasture and in some localities vetch may be seeded with it.

Throughout the dryland country, cattle seem to be the type of livestock best adapted to the climate and the type of feed available. They make good use of native grasses and can be wintered on rough feed and native grass hay.

In extensive areas in many parts of the Plains cattle raising is still the main industry. Rangelands may be concentrated in a large block of country with only limited areas of farmland. What farmland there is may be mostly irrigated. Examples of these extensive range areas are in the Sandhills of Nebraska and the short-grass country in eastern Wyoming, Montana, and several other Western States.

In some areas sheep have been grazed in mountains and foothills. Texas, Wyoming, Montana, California, New Mexico, Utah, and Idaho have produced thousands of sheep as range animals. It is a type of livestock production for low-rainfall regions, but is not classed as typical dryland farming, since in these areas it is chiefly a range type of livestock production and involves a minimum of crop production to support it.

Soil erosion by wind and water has come to be a big problem in nearly all dry-farming areas. Special precautions need to be taken against erosion wherever the sod has been broken and cultivated crops grown. On steep slopes an occasional heavy shower or the water from melting snow may cause severe erosion if the land is in a condition to wash.

On level land, as well as on rolling or hilly land, wind erosion does extensive damage to crops and soils. In practically all dry-farming regions the control of wind erosion is one of the most important points in any system of farming. Wind erosion may not be severe every year, but it is always a threat and can occur almost any year if the principles of control have been neglected.

Sandy soils are more subject to wind erosion, and on them it is harder to control. Fine-textured soils may also suffer from wind erosion, and during long droughts they may suffer from soil drifting.

Some effective yet simple methods have been developed to hold down wind erosion. Some of the more important principles of control are:

Keep the soil covered with a growing crop as much of the time as possible.

When land is not in a growing crop, keep the residue from the previous crop on it by the use of stubble mulch, in which the land is tilled with an implement that pulverizes the soil without inverting it or burying the residue.

Use strip cropping--alternate strips of growing crop and stubble or stubble-mulch fallow.

Make use of cloody fallow.

Use tree shelterbelts or strips of tall growing crops to protect adjoining land.

Use emergency methods of tillage when soil starts to drift.

The equipment needed for use against wind erosion is discussed under methods of preparing the seedbed for wheat.

Steps to avoid wind erosion should be taken at least a year before the time that erosion is most likely to occur. If an attempt is made to control the erosion by shelterbelts, the trees may have to be planted several years before they can be expected to have much effect.

Highly effective in many areas is the stubble-mulch method. It involves the use of stubble, straw, stalks, or other form of residue to reduce the velocity of the wind at ground level and thus reduce its ability to move soil. A common form of stubble mulch is wheat stubble and straw left after the combine. It must be left on the surface during the preparation of the seedbed for the next crop. Row crops that leave a dense stubble may also offer effective protection.

Sudan or sorghum, even though much of the plant is removed for hay or feed, may still leave a dense stubble in the row. If it is cut 6 to 12 inches high, depending on the density, the field may be reasonably well protected. Such stubble should be left upright until the next crop is planted, if possible. Sometimes it is feasible to drill small grain or grass mixtures in the stubble without previous cultivation if there are no weeds. If that can be done, the old stubble may afford effective protection against wind erosion while the new grass crop is getting started. Cornstalks or sparse stubble usually do not give good protection.

A third method, that of using strip crops to control wind erosion, has been widely used in some sections. Alternating strips of wheat and fallow may be 5 to 10 rods wide or even wider. Sometimes they are at right angles to the most destructive winds. Sometimes the strips are on the contour to get the greatest protection against runoff and erosion during a heavy rain. If the fallow strip is handled by the stubble-mulch method, almost complete protection against wind erosion usually can be achieved.

In this system one strip would be in growing wheat, which was seeded on mulched land for protection against soil blowing. The adjoining strips would be receiving the fallow treatment, in which the land is subtilled with equipment that leaves the residue on the surface. After the wheat is harvested, the stubble and straw protect that strip, and the fallowed strip is seeded to wheat. All the land is thus protected at all times.

Cloddy fallow may be used with any type of fallowing; if the surface is left largely covered with clods that cannot be moved by the wind they will protect the fine material from blowing. Fine-textured soils form rather stable clods that protect the soil. Sandy soils do not form stable clods; even if the soil is worked when moist, the clods weather down quickly. The effectiveness of the method therefore depends on the kind of soil.

The use of tree shelterbelts received a great stimulus during the decade 1933-1942. Millions of trees were planted in the Great Plains with the idea that they would greatly affect wind movements and do much toward controlling wind erosion. Narrow belts have been placed at intervals of 20 to 40 rods in some sandy areas.

After the trees reach considerable height under such conditions, they are quite effective in reducing wind damage to the soil or crops.

The use of shelterbelts seems to have about reached its peak, for several reasons: They take considerable space away from the cultivated acreage on the farm; their esthetic value is great, but their economic value may be questionable; we have agronomic methods for reducing wind erosion.

The use of emergency tillage methods is usually brought into use when more effective methods have been neglected. If a cultivated field has no growing crop or residue on it, wind erosion may start. Roughening the surface or a part of it may then stop soil movement over the entire area. Any shovel-type tillage implement, like a plow, lister, or shovel cultivator, will throw up clods or chunks of soil, which will tend to stop soil movement. One or two lister furrows spaced 2 or 3 rods apart across the field may hold the soil or a wheat field from drifting for a while.

It may be necessary to run more furrows between the first ones if drifting starts again. Disk tools may be used to stop wind erosion on tilled land temporarily, but since disk implements tend to pulverize the soil and do not throw up clods, they are less effective than shovel-type tools.

If land is kept covered with stubble mulch, the emergency methods will seldom be needed. Emergency methods are sometimes necessary on a large scale if widespread drought has reduced the amount of mulch protection that can be provided. Some States have laws requiring farmers to use emergency methods when needed.

Water erosion is a more serious problem in the dryland farming area than is generally thought. In the eastern part, a rainfall intensity of 3 inches an hour for 30 minutes can be expected to occur about once in 5 years. The comparable figure farther west is about 1 inch. Only permeable soils or soils protected with residue can absorb rains of that intensity.

The resulting runoff creates a water erosion problem on the more sloping land and on nearly level land if the slopes are long, because the water accumulates on the lower part of the slopes. A stubble mulch effectively controls water erosion, as well as wind erosion. The litter maintained on or in the surface breaks the force of the falling raindrop, reduces the speed with which water moves across the land, and maintains a favorable condition for intake of water at the soil surface. If slopes are so long or steep that residues will not control erosion, mechanical measures, such as terraces and contouring, are needed.

Terraces generally are considered applicable on slopes steeper than about 1 percent, on which even small concentrations of flowing water attain erosive velocities. Terraces intercept the runoff before it reaches damaging proportions.

On long slopes of less than 1 percent, one or more diversions may be needed to reduce the length to one on which erosion can be controlled by vegetative measures.

The diversions may be several hundred feet apart. Even on the gentle slopes some farmers prefer a regular terrace system with closer spacing because they help conserve water. Planting and cultivating row crops on the contour has noticeable benefits in some years and is especially important on terraced land. Contour drilling of wheat is especially beneficial if deep-furrow drills are used.

The term "crop rotation" is less aptly applied in dry-farming areas than elsewhere: There are fewer crops from which to choose and few legumes that canbe generally used to maintain the nitrogen supply in the soil. It is therefore not so important that any particular sequence of crops be followed. One of the main considerations is to arrange the sequence with a view to the possibility of a moisture supply for the oncoming crop. For example, corn (in areas where it is adapted) usually leaves the soil with a better supply of moisture than does small grain. Wheat usually exhausts the available soil moisture almost entirely by harvesttime. Consequently some time should elapse before another crop is seeded. Early preparation of the seedbed after wheat is essential if another seeding of wheat is to follow.

Wheat may often be seeded on cornland from which the crop is removed for fodder or silage. Or it may be drilled between wide-spaced corn rows.

Another reason for not using the term "rotation" so much is the possibility of crop failure. Because of the wide fluctuations in annual rainfall, nearly all dryland areas experience some crop failures or near failures, which may break the sequence of a rotation. Then the farmer has to put in the crop that has the best chance for success under the conditions of soil moisture and weather at the time.

Some examples of types of cropping systems that might be adapted in different parts of the dryland farming areas of the United States are: Corn, wheat, wheat; corn, wheat, fallow, wheat; corn in wide rows, wheat, wheat on early worked land; wheat, fallow; wheat, sorghum, fallow; corn removed for silage, wheat; corn, barley, fallow, wheat; wheat, peas for canning; wheat, grass several years, sorghum, small grain; kafir, cowpeas, milo (Southern Plains).

The type of cropping system used on a given farm has evolved on the basis of the type of farming a man wanted to carry out. Several rather distinct types of dryland farms exist.

The first is the general farm that has considerable livestock. This type usually occurs in localities in which a good supply of range or pastureland is available to supply summer grazing. Enough grain and roughage should be produced to carry the livestock through the winter. Practically all crops produced are fed on the farm. Nearly all the income is obtained from the sale of livestock and livestock products. Some livestock and a limited acreage for feed crops may mean a more stable system and a more steady income than a one-crop wheat system. In many areas the total longtime income may be higher with a wheat system, but that, it must be admitted, will mean some total failures. The farmer must decide whether he can stand the financial strain in order to realize more income in the long run.

Another type of mixed farming is the cash-grain farm, in which the returns are from the sale of grain, seed, or hay.

The wheat farm derives practically all its income from the sale of wheat. The farmer lives on the land and devotes his time chiefly to this one enterprise.

The "suitcase" farmer is the absentee wheat grower. He may have a profession or business in a city and occasionally visit the farm or employ someone to do the farm work. He does not become part of the farm community. He may not see the wind erosion in the spring; maybe he does nothing to help control erosion during that season.

Some farmers try to adjust their plantings on the basis of the moisture present in the soil at seeding time. The practice returns a higher total income over a period, although there may be considerable variability from year to year.

Suppose a man started out on the basis of a wheat-fallow system. If good rains should follow harvest, he might get moisture into the soil to a depth of 2 feet or more. Then he might decide not to fallow the land the following year but to put it back to wheat for another year. Likewise, if he held wheatland over with the idea of fallowing for another wheat crop, but found the soil well filled with moisture by spring, he would have the choice of several crops. He could hold it over for wheat, but would produce no crop that year. Instead he might plant the land to corn, sorghum, potatoes, or some other crop and thus make use of the soil moisture as soon as possible after it had been stored.

This idea of farming according to the moisture supply offers a basic principle for the dryland farmer. If he would plant a crop in season every time he has an adequate supply of soil moisture and leave the seed in the bag when he does not have the moisture, he would put his farming on a more realistic basis. He would be taking less of a chance with the possibility of rain after the crop is planted. If the idea were adopted, a tile spade or a soil auger should become standard equipment on a dryland farm. Either of those tools permits a farmer to determine quickly the depth to which the moisture has been stored in the soil.

Available soil moisture is one of the main concerns in dryland farming. The rainfall during the time a crop is on the land seldom is enough to produce a good crop. It is necessary therefore to have some reserve moisture stored in the soil before the crop is planted.

Research workers of the Kansas Agricultural Experiment Station at Hays found that when wheat was seeded in dry soil with no available moisture stored in the subsoil the average yield of wheat was 4.9 bushels an acre; when the soil was wet 1 foot deep at seeding time, 8.7 bushels; wet 2 feet deep, 15.2 bushels; and when wet 3 feet deep or more, 26.5 bushels an acre. The uneven distribution of rainfall and the frequent occurrence of extended dry periods has led to the practice of fallowing. This means keeping the land free of a crop or weeds for a period of time so that moisture and nitrates may be accumulated in the soil for use by the next crop.

A year of wheat followed by a year of fallow has come to be a common practice in the wheat territory. A wheat crop is harvested in the central Great Plains in July. Unless the field becomes weedy the land is allowed to lie without treatment until the following spring, when tillage operations for fallow begin. The land to be fallowed would be one-wayed or plowed about the first of May or about the time weeds or volunteer wheat start. The land is then worked often enough to keep down weeds, but do it to break the crust on the surface of plowed land, to reduce runoff during the next rain, and to avoid wind erosion on smooth, crusted soil.

Work at numerous dryland experiment stations has shown that deep working of the soil has not perceptibly mitigated the effect of drought. It has not increased yields of crops enough to be profitable, no matter what method has been used to deepen the cultivated layer of soil. Despite the proof furnished by 60 years of experiments, which have failed to show any consistent profit from deep tillage or tilling into the subsoil, interest in the practice waxes and wanes periodically. Perhaps deeper tillage may be of some value in connection with the deeper placement of fertilizers, but that point has had little study in regions of limited rainfall.

Fertilizers have been used very little in most of our dry-farming areas, as those soils are reasonably well supplied with the mineral elements plants need. In some places the addition of phosphorus has given favorable results. Enough nitrogen usually is present to allow crops to make use of the available moisture--especially if a crop follows fallow.

Fallowing not only allows the soil to store water, but it accumulates nitrates at the same time. The use of nitrogen fertilizer on fallowed land has given little return in most places and usually has been considered impractical. On some soils, particularly the sandier types, good results from nitrogen fertilizers have been obtained, even on fallowed land. Increases in yield of grain, straw, or protein content have been obtained under many conditions.

As to the future: As the fertility of dryland soils is gradually reduced through cropping, greater returns from the use of fertilizers can be expected. After a half century of farming, nitrogen fertilizers may begin to show greater returns on many dryland soils. If one crop follows another without an intervening fallow, added nitrogen in the form of fertilizer may offset somewhat the effect of no fallow, especially if the moisture is reasonably adequate. Chemical analyses of soils in various parts of the dryland region have shown that they have lost 25 to 40 percent of their total nitrogen since the land was put under cultivation.

Since many of the soils have been farmed for only 30 to 50 years, the loss can be considered serious. The use of nitrogen fertilizer would appear to be only a matter of time. The need for phosphorus or other mineral elements will be ascertained for various localities as the land continues to be farmed.

The use of barnyard manure has given only slight returns. Likewise green manure has not been very effective in improving the growth of the following crop. The benefits from these treatments may increase after the land has been farmed for a longer time, and further experiments determine the most effective methods of using them.

Some farmers burn straw and stubble before preparing the seedbed for the next crop. Often they have found that the yields were as high as from land where the straw was not burned. Since tillage was easier after burning, they have asked whether the practice is sound. The explanation of the good yields following the burning of stubble involves several points. In the first place, burning all the trash on the field makes possible a good, smooth job of plowing.

The rate of nitrate accumulation may be increased for a time after the straw is burned. The soil micro-organisms which cause straw to decay use some nitrate present in the soil for their own growth; consequently in the burned area this reaction does not take place and more nitrate may be stored for the immediate use of the wheat crop. If the straw is burned every year for a few years, however, the advantage in improved yields at the start gradually disappears. The land to which straw was returned may then give the higher yields.

The great advantage in returning straw, instead of burning it, is that the straw increases the capacity of the soil to absorb water and protects it against wind erosion. The nitrogen returned with straw amounts to about 10 pounds a ton of straw.

The equipment for dryland farming used by the early settlers was what they took along with them. The tough grass sod was first broken with a sod plow, or prairie breaker, which had a long moldboard, or steel bar, for inverting the furrow slice.

In later years came the stubble plow, which had a much shorter moldboard. It turned the furrow slice and did much pulverizing of the soil.

Much of the early research on the dryland experimental farms was concerned with the time and depth of moldboard plowing for various crops. Plowing was a good way to start preparation of a seedbed, but later people realized that it had some shortcomings. It permitted much erosion during heavy rains and exposed the soil to severe wind erosion.

Other types of tillage tools have been introduced since. One of the most widely used is the one-way diskplow. It stirs the soil, gives a minimum of trouble in operation, and land can be covered rapidly with it. The principal objections are that, being a disk implement, it tends to pulverize the soil too finely and tends to bury the crop residue too completely. It may be used for the first operation to kill weeds and volunteer plants, but if used a second time or more it may bury most of the residue and lead to wind erosion.

A more appropriate implement for the second and later operations is the subtiller, usually a V-sweep-type machine that has come into use for stubble-mulch farming. By the careful use of subtillers, enough residue may be preserved from one crop to hold the soil until the next crop is started to control wind and water erosion. With this stubble-mulch system, of course, other useful methods should be used--practical cropping systems, stripcropping, cloddy fallow, and sometimes terracing.

The use of power machinery has helped the dryland farmer immeasurably. Tractors and large equipment enable him to do his tillage, seeding, and harvesting operations in less time and at the most advantageous time. Timely operations may be of importance not only for the crop but also in the control of insects and diseases.

Reseeding dry-farming land to grass has been suggested as a way to treat the drylands that are not well adapted to cultivation.

A considerable amount of reseeding is done by farmers who need additional pastureland to support their livestock program. But many farmers feel that they will realize a higher return from the land if it is in cultivated crops. Another reason why reseeding to grass is not done more widely is that it is hard to establish grass on cultivated land. Very dry weather may follow seeding, so that germination will be low and the chance for survival of the seedlings greatly reduced. Only about one-third as much land is seeded to grass in the 17 Western States as is seeded in the rest of the country.

The types of grass used in different parts of the dry-farming area vary with climatic conditions. The methods of seeding also vary widely. In order to conserve moisture and obtain protection against soil blowing, much of the grass seeding is being done through some sort of residue cover. In the Northern Plains it is common practice to drill grass seed into wheat stubble in late fall with no previous seedbed preparation. The seed is then in the ground ready to germinate and start growth with the first warm days of spring, when the soil very likely is moist enough.

In the Southern Plains some tillage of the seedbed may be given, but the seeding is best done with drills that have depth gages, so the seed will be planted deep enough to get moisture but not so deep that the seedlings cannot come through to produce a good stand. Seeding with some protective residue cover aids in holding moisture for germination and prevents the young plants from being blown out or from being cut off by blowing soil or sand particles.

TROPICAL AND SUBTROPICAL AGRICULTURE

Optimum production of crops is effected by addition of fertilizers and amendments to soils of good physical structure. More often than not, however, measures to curtail losses from leaching and erosion, to improve water relations, to maintain soil organic matter, to rehabilitate worn-out soils, or to reclaim waterlogged or saline soils are necessary before a soil fertility program can be utilized to advantage. Soil management begins with clearing of the virgin cover, be it tropical rain forest, savanna, or grassland, and continues so long as the soil is used for agricultural purposes. Perhaps in no other part of the world are soil management measures more important than in the tropics and subtropics (Jacks and Whyte, 1939). Failure of agricultural systems to comprehend the significance of erosion, as well as intensive weathering under hot, humid conditions, has brought about the widespread distribution of poor, badly eroded, infertile soils all over the tropics and subtropics. Intensive management is needed to return these lands to productive agriculture and to retain fertility and good structure in those which now possess them.

Three general systems of agriculture, exclusive of livestock farming, are practiced in the tropics and subtropics: paddy (padi) or lowland rice; patch, "ladang" or "kaingin" (shifting culture); and intensive culture (Lowdermilk, 1934; Russell, 1950; Robinson, 1950; Jackson and Sherman, 1953; Pendleton, 1954).

Paddy culture is one of the outstanding features of the lowland tropics. The major requirement of lowland rice is water. Wherever rivers, lakes, or canals can be diverted the crop may be grown. Generally, paddy fields are located in level terrain, although hillsides may be terraced at an infinite expense of labor as long as there is possibility of irrigation. Lowland rice is the major grain, the basic diet of millions of people in the tropics. It can be raised successfully on land too poor to support almost any other crop. Paddy fields, unlike patch plantings, are farmed year after year in the same place, sometimes for generations, soil fertility being maintained by careful management and continual replenishment of nutrients from organic matter and the water that flows slowly over the areas. Paddy culture is destined to remain the mainstay of tropical agriculture for small farmers in many countries until ways and means are developed for reclaiming the fertility of upland soils on a broader scale than is now possible.

Patch, ladang or kaingin, culture is the type of agriculture utilized by small holders on land incapable of being flooded for paddy. It consists typically of clearings opened up in the jungle around a village. During the dry season, the farmer cuts the trees back to poles, felling the larger ones, and piles up the underbrush so that the trash may be burned or the large pieces sold for fuel after it has dried. Crops are planted in little holes for one, two, or three seasons until the soil has lost its fertility or weeds cannot be overcome with the simple hand tools that are used. The clearing is then abandoned and the practice repeated elsewhere. Mainly food crops are planted, but cash crops, such as cotton, rubber, cacao, coffee, and tobacco, may also be grown. Patch culture is at best a subsistence agriculture, since the small plots will provide little more than enough to feed the family during the year. It is extremely wasteful of land as five, ten, 15 years or longer periods are required before the forest returns and the same plot can be replanted. This means that each farmer needs ten to 15 times more area to grow his crops than a single, well-fertilized plot on better soil. Oftentimes, the serious grass pest cogon (Imperata cylindrica Beauv.) obtains a foothold in the clearings before the forest fires kill out the seedlings of forest trees, enabling the cogon to convert the area into savanna. A stand of cogon is so dense that it cannot be cleared with hand tools, and the intense root competition smothers out crops planted among the grass. A partial solution in central Africa is to hill the soil up into mounds and plant the crop on top. The intrusion of cogon into forest clearings has converted extensive areas of Asia and Africa to savanna, areas which are lost to agriculture until the grass can be plowed out and destroyed by power equipment.

Intensive culture in the tropics and subtropics falls into two general categories, plantations and small holdings. These provide the world with bananas, citrus, pineapples, coffee, cacao, tea, rubber, spices, copra, palm oil, sugar cane, fibers, and other crops. Some of them require such simple processing that small holders can grow them as cheaply as plantations. In other cases, the advantages of large-scale production are secured by cooperatives. This is particularly true with those crops which require large areas to support a factory or processing plant of economical size or whose markets are principally in export trade. Cash crops in small holdings are of definite value to a country. The number of farmers engaged in raising them may be expected to increase as fertility and management practices developed by governmental agencies and plantation personnel are adopted.

REMOVAL OF PLANT COVER

Preparation of land in tropical and subtropical regions consists of removal of the existing plant cover in such a way as to effect the transition from forest or grassland to intensive crop culture with minimum disturbance of the natural equilibrium of soil, vegetation, and climate. Forests or grasslands can be cleared with machinery, hand labor, or a combination of the two. Where a new plantation is being opened and the terrain is relatively level so that erosion is not a serious problem, all of the operations may be carried out with power equipment, such as bulldozers, road scrapers, stump pullers, and the like. If labor is readily available, the area is small, or the land is steep, clearing may be done entirely by hand labor using axes, saws, mattocks, shovels, and hoes. Both have their advantages. Heavy land-clearing equipment like bulldozers with their cleated tracks churn up the ground thoroughly, but they can clear large areas quickly and economically. Hand labor is slower, although selectivity can be exercised in removal of trees and herbaceous cover which might be retained to help reduce erosion while clearing is in progress. On the average plantation where an area up to 100 ha. may be opened at one time, it is generally less expensive to use hand labor for some of the operations, with tractors, road scrapers, chain saws, and similar equipment to aid in felling trees, getting out stumps and roots, leveling the land, building terraces, and other heavy work. Such machinery will be used in maintenance around the plantation later on and should be available when the land is being cleared. Draglines or ditch diggers are helpful for making drainage ditches. They and other heavy equipment may be rented as the need for them arises. Certain laborious, time-consuming tasks like digging out large stumps and boulders can be expedited by the judicious use of explosives. If the plantation manager or one of his men is expert in handling them, they can be useful in many other ways, as for instance, digging large drainage ditches. The small holder who wishes to clear a hectare or two will generally do everything by hand, aided perhaps by a tractor.

The first step in opening a plantation involves a detailed survey of the terrain. Sites for the factory, office, manager's and laborers' housing, and accessory buildings are selected at this time even though their location may have to be changed after clearing is completed. Ideally, they should be in as nearly a central spot as availability of adequate water supplies and considerations of health and accessibility will permit. The land to be cleared is parceled off into blocks which may be any convenient size and dimensions. If the topography permits, they are square or rectangular, four or five hectares in extent, and oriented with the edges north-south and east-west.

Clearing of virgin or old second-growth jungle, densely forested areas, and of young second-growth jungle, savanna, shrub thickets, or grassland follows the same general pattern, except that removal of large trees does not pose a problem in the latter group. Where the blocks are cleared by hand labor, they are divided into about ten sections. Gangs of six to eight men work with axes and saws in alternate sections so that trees may be cut down without endangering anyone. Each gang or pair of gangs has a tractor equipped with a chain to aid in felling trees and large clumps of underbrush as well as for dragging off trash. Starting at the uphill side of the block, the men first clear away the underbrush and small trees up to a diameter of 25 cm. to make room to fell the giants. The portion of the area designated as the plantation watershed may be selectively thinned or left intact. The largest trees are cut down last. Timber that is too small to be sawed up into lumber is laid horizontally across the slope, dumped into ravines, or piled up for burning in areas that will not be planted. The ashes from burning have a beneficial effect on acid soils but are not recommended on neutral or alkaline soils. Also, if the piles are made too large, burning may sterilize the soil around them.

After the underbrush, termite nests, and trees are removed, the stumps and larger roots remain. These may simply be left to rot if the crop is not particularly sensitive to root rot or does not command a high market price. Stumps and large roots close to the surface, however, are an unmitigated nuisance, as they make regular planting and machine cultivation almost impossible. Several methods are possible to effect their removal. Stumps may be dug around and cut off at a depth of 60 to 75 cm. below the ground level. A tractor with a heavy chain may be used to pull them out. Large stumps, if they are reasonably sound, can be blown out with explosives. A stump puller may be used. (This is a heavy crawler-type tractor equipped with an apparatus designed and operated like a dentist's forcepts.) Large roots and smaller stumps may be removed by a bulldozer equipped with a scarifier instead of the usual blade. The scarifier has stout steel fingers which effectively rip up the ground to a depth of 30 to 60 cm. Three additional systems of ridding areas of roots and stumps have been worked out in the Far East where clearing is done almost entirely by hand labor. Strip or semiforest cultivation was originated in Malaya by Birkmose and has been used extensively in Indonesia for rubber and other crops. Wide strips along the contours or parallel to the rows are cleared and cleaned of stumps in the jungle, and the crop is planted in these, leaving the borders intact. The system reduces erosion, but its disadvantages are excessive shading, root competition, continued loss to a certain extent from root diseases, and the danger to personnel from wild animals. Ditch clean clearing or step clean clearing has proved beneficial to tea and rubber. Ditch clean clearing consists of digging a trench about 60 cm. wide, as deep as needed, and 4 to 5 m. long. Soil from one side of the trench is worked and then the other before the trench is moved forward. The work is tedious, but results in thorough removal of even small roots. Step clean clearing is more intricate and needs more supervision, but the soil is left more or less intact. The system consists of cleaning the soil in layers which are piled on top of those previously cleaned. The chief problem in clearing young second-growth jungle, savanna, shrub thickets, and grassland is to rid the soil of rhizome mats of noxious grasses like cogon. The simplest way is to plow up the land and rake it several times with laborers trailing after the tractor to pick up loose pieces of rhizome.

A good transportation network enhances economical operation of a plantation. Major access roads, railway lines, canals, bridges, and dams are generally contracted to engineering firms which specialize in construction. Other roads, paths, drainage ditches, and similar structures are built by plantation personnel. If it has not already been done at the time of laying out the blocks, a detailed topographic survey is made. In flat terrain, the roadways are run along the boundaries of the blocks; in hilly land, they follow the contours as nearly as possible. Roads for trucks and other vehicles are graded to a slope of not more than eight degrees and for pedestrians or riders not more than 15 degrees. Main roads are usually made about 6 m. wide, while roads in the interior of the blocks are about 3 m. Heavily traveled roads are gravelled or asphalted; those with light traffic are sodded with grass and gravelled only in heavily shaded spots. They should have a slightly rounded crown so that they shed water easily into ditches on either side. Ditches along the roadways may conveniently be made part of the over-all drainage system of the plantation, in which case they are shallow or deep, wide or narrow, depending on the volume of water they must carry. The sides of the ditches nearest the road are made with a long gentle slope, if possible, and reinforced with material such as sod, stone, or rip-rap to protect against washouts. Low stone or sod dikes, 25 to 30 cm. high, or wood pales are installed in the ditches at intervals of 20 to 25 m. to slow down the water. Ditches along roads bordering the plantation or waste areas of forest are made deep enough, usually 1 to 2 m., to check competition from roots of the wild plants. Paths are made in the interior of the blocks to afford easy access by the laborers to all parts.

CONTROL OF EROSION

The most important phase of soil management and probably the outstanding problem of agriculture in general is the control of erosion, which is caused largely by the interference of man with the equilibrium that exists between soil and its environment. Natural erosion, or weathering, is normally a slow process even under the drastic conditions prevailing in the tropics, and, as long as the soil is covered with vegetation, thousands or millions of years may be required for complete destruction. Catastrophic erosion occurs when man or some other agency disrupts the natural equilibrium, and the soil is exposed to the full force of rain, wind, and sunshine. Then, loss of soil by actual removal or oxidation is vastly accelerated, and within a few years, or in extreme cases a few months, material that has taken centuries to reach its present fertile, friable state is reduced to bare, unweathered rock.

Soils of the humid tropics and subtropics are particularly vulnerable to erosion from torrential rains which are characteristic of these regions. Control of erosion in these and other areas has been an age-old problem. Early civilizations in China, India, Ceylon, Malay Archipelago, Asia Minor, Africa, the Mediterranean region, and the Americas were well aware of the destruction caused by denuding lands of their vegetation through overcropping and overgrazing and devised measures to conserve and protect the soil. In certain regions, notably the Asiatic tropics, two systems are still widely used by native populations. One of these, paddy or lowland rice, is the mainstay of agriculture on lands that can be flooded. Loss of soil is confined for the most part to fine sediment swept away in the water as it moves slowly across the fields on its way to the sea so that lands in the upper parts of a watershed gradually lose their fertility.

HORTICULTURE

Development counselors have found that local conditions will determine the feasibility of attempting to improve existing systems of fruit or vegetable production. Disease and insect problems make the introduction of new plants extremely difficult. Crossbreeding and/or grafting may help to solve disease problems but these should be considered only at the advanced stages of development. Mechanical control or hand killing of insects may prove adequate where labor is plentiful and spraying impractical.

The manual makes no attempt to discuss varieties of vegetables, fruits or crops, because of extreme variations of species and growth factors in different locales. Study and observe the existing situation before making recommendations. Expand and improve the growing and uses of local fruits and vegetables as the most feasible means to improve village horticulture. Methods of curing and storage often provide a means to a yearly supply of vegetables and some fruits. An underground potato cellar may provide storage, or natural cooling might suffice. (For drying, see Sun Drying of Fruits and Vegetables under Home Industries.)

1. Fruits. Principal fresh fruits of world commerce are the grape, apple, orange, pear, plum and banana; principal nuts are the almond, Brazil nut, chestnut, coconut, filbert, pecan and walnut. Large quantities of fruits are dried, canned, frozen and otherwise processed. The grape, including grapes grown for wine, for drying and for table use, is the leading fruit of the world.

The apple is the most important tree fruit of the temperate zone. The orange is the most important commercial tree fruit of tropical and subtropical regions. The date is an important crop in the drier areas of the world. There are more species of fruit in the tropics than in any other region, but most of them are only of local importance because of their highly perishable nature. The four of greatest commercial value are the banana, pineapple, coconut and Brazil nut. Others include mango, avocado, papaya, guava, sapodilla, cherimoya and prickly pear. The mango is as important to the people of India as is the apple to the inhabitants of the temperate regions. The banana is the great starch food of the tropics.

In the growing of fruits, the first factor to consider is the kind of fruit to be grown. The variety selected should be well adapted to the particular section of the country in which the enterprise is to be located. Successful fruit growing requires careful attention to all production practices, particularly spraying for pest control.

Having selected the location and the kinds of fruits to be grown, the particular area of the farm on which the fruits are to be grown should receive consideration next. Soil is the most important factor in selection of the site. Fruits will grow on a fairly wide range of soil types but, in general, fruit plants grow and produce most satisfactorily in a soil that is at least moderately fertile, well drained, well aerated (so that the roots may penetrate deeply) and adequately supplied with moisture. The presence of an abundance of organic matter in the soil is a great aid in retaining moisture. Fruits usually do best on slightly acid soils.

2. Vegetables. Because of their bulk and their perishable nature, fresh vegetables do not figure prominently in world commerce as do fruits and nuts. In domestic commerce, however, vegetables surpass fruits in value. The sweet potato is a universal food crop in the tropics and offers much promise for development.

The vegetable garden is primarily to provide food for the family, yet it may reach considerable economic importance in the aggregate. The size of the garden will be dictated by the size of the family, the interest in gardening, the labor available and the geographical location. Following is a suggested plan for a garden 30 to 60 ft. for temperate zone conditions and arranged in numbered rows according to season of planting: (1) asparagus; (2) lettuce and radishes; (3) spinach, followed by cucumbers and bush squash; (4) onion sets; (5) early turnips, mustard, cress; (6) early beets, followed by late cabbage; (7) onions; (8) parsley, carrots; (9) parsnips; (10) early peas, followed by string beans; (11) cabbage, cauliflower; (12) lettuce, followed by celery; radishes, followed by celery; (13) late peas; (14) string beans; (15) early sweet corn, followed by turnips; (16) late sweet corn; (17) dwarf lima beans, peppers; and (18) tomatoes and eggplant.

3. Propagation of Plants. Horticultural plants are propagated (i.e., increased in numbers) by two methods, namely, by seedage (sexual propagation) involving the formation and planting of seeds, and by vegetative means (asexual propagation) involving the use of a portion of the plant other than the seed. Propagation by seed is employed for plants which provide an abundance of seed and which can be bred readily to uniform and pure lines, as most annual flowers and many vegetables. Hybrid seed, such as that used for sweet corn, is produced by developing two pure lines and then combining them by cross-fertilization. Such seed may produce superior yields, but seed taken from plants raised from hybrid seed should not be used for reseeding.

Seed of herbaceous plants, such as tomato, onion and zinnia, will germinate as soon as it is mature. On the other hand, seed of many wood plants must be afterripened before it will germinate. Thus, peach seed requires 12 weeks at about 41° F., under moist surroundings, and apple seed requires 8 weeks at approximately the same temperature. In nature, these conditions are provided out-of-doors in winter. Nurserymen and plant breeders either plant such seed in the early fall, or provide similar conditions by stratification in which seeds are placed in boxes or trays in alternate layers with sand, soil or peat moss and stored at temperatures of about 41° F. for the period of time required for the particular seed under treatment.

Plants are propagated vegetatively from portions of leaves, stems or roots. Although in propagation by seed each plant varies somewhat from every other plant in the lot, in vegetative propagation all daughter plants are identical in genetic make-up and are also identical to the parent plant from which they are secured. This is of great importance in horticulture, since it means that a single plant with desirable characteristics can be retained and perpetuated, identical in all respects to the original. None of the common tree fruits, such as the apple, pear, cherry, plum and peach will produce true from seed;

distinctive horticultural varieties, such as the Northern Spy apple and the Washington Navel orange, are propagated by vegetative means.

A combination of both seedage and vegetative propagation is common with many woody plants, such as fruit trees and roses, in which an inexpensive seedling root is raised from seed and upon which the desired variety is then budded or grafted. The portion of a plant which serves for the root or underportion is called the rootstock or stock, and the portion of a plant which is placed upon the stock is called the scion. The resulting plant is thus composed of a seedling root and a known-varietal top and may be termed a stion (combination of stock and scion). In combining a stock and a scion, various techniques are employed, all of which are a form of grafting. A common form is called budding in which a single bud is grafted onto the stock during the active growing season, as contrasted with grafting with dormant scions in midwinter or early spring. Strains of plants which are propagated by vegetative means are called clones.

Humidity, light, temperature, soil, rooting medium and the nature of the material itself play important parts in the method of propagation selected and the results secured. Continuous artificial mist has aided in the rooting of softwood cuttings; synthetic growth substances, such as indolebutyric acid, have increased the speed and degree of rooting; and synthetic plastic films, such as polyethylene, having proved of great value in air layerage and in propagation of cuttings.

4. Pest Control. Pests of horticultural plants are controlled by both natural and artificial means. The development of varieties which are resistant to certain pests has become one of the important functions of plant breeding. For example, resistance to mosaic virus has been bred into red raspberries, wilt resistance into tomatoes, powdery mildew resistance into canteloupe and nematode resistance into peach understocks. Artificial controls include crop rotation, purification and grading of seeds, soil cultivation, sanitation, soil fumigation, placing of mechanical guards as protection against rodents and spraying, dusting and dipping with various fumigants, fungicides and insecticides.

Common insecticides include arsenate of lead, used as a stomach poison against chewing insects; nicotine, pyrethrum, rotenone, dinitro compounds and oils, used as contact insecticides; and hydrocyanic acid, carbon disulfide, paradichlorobenzene, ethylene dichloride, used as fumigants. Common fungicides include various sulfur compounds, bordeaux mixture and copper and mercury compounds.

5. Harvesting and Storing. The time of harvest is dependent upon the nature of the crop itself, the use which is to be made of it and the facilities for storage. Beans are harvested in the green, immature stage when used as snap beans, but are left until full maturity when used as hard-shell beans. Among the indexes of maturity are changes in color, changes in the pressure required to puncture the flesh as measured by a mechanical pressure tester, and the predetermined time interval between full bloom and the usual harvest season.

Both common storage and artificial cold storage are used for horticultural products. Common storage depends upon natural outdoor temperatures and is provided by basement storage rooms in residences, by boxes or barrels sunk into the ground and by specially designed pits, caves and ventilated buildings. Cold storage is provided by refrigeration in specially constructed and insulated buildings.

HOME GARDENS AND LAWNS

The management of our garden soils follows the same principles as the management of field soils, but we use different practices. In our gardens we aim for variety, and we have a wide range of plants--grasses, annuals, perennials, shrubs, vines, and trees.

We try to have flowers and fruits through the seasons and ornamentals for sun and shade. Yet the total number of plants is small, and we can treat them individually. Even with simple handtools, we have a chance to apply the principles of soil management over a wide range of combinations more precisely than the farmer can do for a few crops in big fields.

We have little choice in selecting our garden soils. Rarely can we choose level, stone-free, sunny, "rich loam" soils, which are recommended so blithely in the garden books and on the backs of seed packets. Once the location of the house is fixed, we must take the soils we find and make the best of them. Oftener than not, the soils around the house are not well suited, as they are, to the plants we want to grow, especially if builders have destroyed the natural surface soil and left thin topsoil over fills of trash and raw earth.

Thus many new home gardeners may begin with soils that are too hilly, too sandy, too clayey, too dry, too wet, or too infertile for good gardens. But good garden soils can be made from them.

By "garden, " I refer to all the cared-for soils and plants around the home--the kitchen garden, flowerbeds, lawns, and plantings of trees and shrubs. Included is a variety of plants that have unlike soil requirements. Some need shade. Others want full sun. Some prefer a slightly acid or neutral soil. Others do best in strongly acid ones. Some should have high soil fertility, others do well in poor soil.

The central problem of soil management in gardens is to develop and maintain a proper relationship between each plant and the immediate soil in which it grows.

Aside from pure luck, the gardener's success depends upon knowing two sets of factors: The requirements of the different plants he can grow and the characteristics of the soils in his garden.

Some plant can be found for almost any kind of soil as it is.

And almost any kind of soil can be modified by management to grow any climatically adapted plant if one is willing to go to the trouble. Most successful gardeners try to find satisfying combinations of plants that require a minimum of soil change for good growth. Yet others go to a lot of trouble to change their soils to make them suitable for particular plants they want to have in their gardens. Some may even make drastic changes in a soil already about ideal for azaleas to have one suitable for roses, or the other way around.

One could hardly overemphasize the critical relationship between a plant and the soil in which it grows. Admiration of a plant in the catalog, at the flower show, or in a friend's garden is not enough of a basis for deciding to put it in our own garden, unless we know that its requirements can be satisfied by our garden soil as it is or as we can change it.

Gardening is an art, and many home gardens are outdoor living rooms. No one can say what is practical for home gardeners in general. Some are satisfied with almost any kind of green and growing things as long as the soil is nearly covered and the plants look healthy--a sensible goal for persons with only a mild interest in gardening.

A large money budget is not necessary for a good garden, even on poor soil. Far more important is the work budget--the care and attention the garden will be given throughout the season, not simply during a short spring bustle that is followed by neglect in summer and autumn.

The place for the garden is normally near the house. Even the kitchen garden is best there unless the soil in some distant place is a great deal better for vegetables and fruits. Near the house there is time to do the little things, before a pest, a drought, or a nutrient deficiency becomes serious. The watchful eye of the gardener is the best fertilizer for his garden.

To begin a garden, we need to know several things about our own place:

The basic soil conditions; the air drainage and frostiness; the water supply we can count on, both natural and artificial; the light that falls on the plants during the seasons; and the protection required against hazards of wind, tree roots, and animals.

To learn about the soils we must dig--not simply into the surface, but down to about 3 feet or even more, if deep hardpans or other barriers to roots and water are suspected. The lower layers of soil control the supplies of nutrients, air, and water for deep roots. The movement of water out of the surface soil itself depends upon permeable layers beneath.

Most soils consist of a series of definite layers, or horizons, one above the other, with different colors and other properties. The horizons have been produced by the longtime effects of the climate and vegetation acting on the mineral matter. The horizons collectively are called the soil profile. Very young soils may not have horizons. Examples include those in the flood plains along streams, recent sand dunes, or new soil made by earthfills. If the gardener digs into an ordinary upland soil and finds no regular horizons, he can be reasonably certain that the soil has been moved about and mixed up not long before.

The main things to look for are depth, texture, structure, color, drainage, the slope and exposure, acidity, nutrients, and contamination.

Depth. Three kinds of soil depth are important. The dark-colored surface soil is normally the most mellow and most fertile. This is deepest in the black soils developed under grass, like those in Iowa and the Dakotas. It is normally very thin in the desert and only moderately thick under the forest of humid regions. On steep slopes it is commonly very thin. Builders often destroy this dark-colored surface soil completely or may cover it with raw, earthy material from excavations.

Then we need to know the depth of the whole soil, both surface soil and subsoil (or A and B horizons), over the raw substratum of weathered rock or other earthy material that has not been changed to true soil.

Finally, we should know how deep the whole soil and other loose, earthy material is over solid rock. The material under many soils is loose and porous to great depths. Other soils are thin over hard rocks with only a small space for roots and water storage. Such soils generally can support only drought-resistant plants that normally have shallow roots.

Texture. The relative proportion of sand, silt, and clay, or soil texture, of each horizon is important because it affects many other properties and because many recommendations are keyed to it. The texture in most soils changes from horizon to horizon. Commonly the subsoil, or B horizon, contains more clay than the surface soil above it or the substratum beneath it.

Classes of soil texture start with sand, which has only a little silt and clay. Then with increasing amounts of clay, the principal classes are loamy sand, sandy loam, loam, silt loam, clay loam, and clay.

With a little practice, you can easily distinguish them by squeezing a moist sample of the soil between your fingers. The sands are harsh and gritty, and the particles scarcely hold together at all. Loamy sands are gritty, too, but the particles cling together when moist. At the other extreme, clay can be squeezed into a smooth smear. The silt loam makes a rough and broken smear. Clay loams are intermediate. Loams give only a very rough smear; sandy loams give scarcely any.

Garden soils of intermediate texture--the sandy loams, loams, and silt loams--are easiest to handle. Sands and loamy sands are permeable, but they hold rather small quantities of water and are said to be droughty soils. Clays tend to become hard and massive unless they are handled carefully.

Structure. The individual soil particles in the ideal garden soil are grouped into stable granules or crumbs. Next best are blocky, nutlike aggregates, between which roots and water can move. Worst of all are the structureless soils.

At the one extreme are sands, in which each grain is by itself. Such soils hold little water between rains and are easily blown about by the wind.

At the other extreme are massive soils with no regular structural forms. Commonly clayey soils deficient in organic matter become massive if plowed, stirred, or walked on when they are wet. But massive hardpans can form from loams and even from sands with some cementing material to hold the particles together. Wherever they occur within the depth of normal rooting for garden plants, such massive soil must be reworked to make it granular or blocky. It is not enough simply to break up massive clods of clay. Organic matter must be added, or the fragments flow back together into masses when they are wet again.

Color. Soil color by itself is not important, but it suggests other conditions that are. Color, along with other evidence, can tell the gardener a great deal about drainage, the amount of organic matter in the soil, and the general level of productivity.

Brownish-black and dark-brown colors generally suggest a good supply of organic matter. In wooded areas where the normal upland soils are brown, black colors in the surface of soils in low ground suggest muck and poor drainage. Well-drained soils developed under tall grasses, like many in the Middle West, have black or nearly black surface soils. But a few black soils are poor in organic matter and easily lose their structure and become massive.

Solid red or yellow colors generally (but not always) suggest fairly good to free drainage. Yellow suggests leaching and a low supply of plant nutrients. So do the grays or whites in upland areas of good drainage. But in low ground, especially if the surface soil is nearly black, gray horizons (called gley) indicate poor drainage--too poor for ordinary garden plants. White colors in dry regions suggest too salty or too limy for most plants.

Some horizons beneath the surface are mottled. Imperfectly weathered rock just above the solid rock may look like this. But the commonest cause of mottling in soils is imperfect drainage, now or in the recent past: The soil is saturated with water, or waterlogged, part of the time and pervious to air, or aerated, part of the time.

Drainage. Imperfectly drained soils that are well drained during the summer and wet only in winter and early spring can support annual garden plants, but the roots of perennials cannot live over the winter in them. Even annuals do poorly if periods of waterlogging occur during their growing seasons. Often there is little evidence in the surface soil alone of poor drainage beneath. Thus it is important that you identify such conditions in advance so you can take appropriate steps for drainage or for plant selection.

If you have any doubt about drainage, you can dig some holes to the depth that roots normally grow--say to 2 or 3 feet, depending on the plants--and fill them with water. For all garden plants that require well-drained soils, the water should disappear within 30 minutes or an hour. If it does not disappear within 24 hours, only shallow-rooted plants could be expected to survive.

Slope and exposure. The slope of the surface soil has a lot to do with drainage, runoff, and erosion. Highly permeable soils that admit water rapidly can be used for cultivated plants on fairly steep slopes. On soils of slow to moderate permeability, small terraces are needed to slow down the runoff water, partly to give it more time to soak into the soil and partly to prevent washing.

You need to look at the whole slope, since it may begin above your garden and carry water from higher ground over your garden. If so, you should plan a diversion terrace on the upper side of the garden to intercept the excess runoff water and to guide it harmlessly to a prepared outlet.

Water tends to accumulate on nearly flat soils that are only slowly permeable unless ditches or special drains are made.

The direction of the slope is often critical. South-facing slopes in warm areas may be too hot for plants that do well on north-facing slopes. Many gardeners in warm areas find it easier to maintain good bluegrass lawns on north-facing slopes than on south-facing ones. The south-facing slopes in cool sections may be much better than north-facing ones for vegetables and flowers that require a warm surface soil.

Acidity and nutrients cannot be seen, of course. They can be guessed at from the vigor of growing plants. The soil in which blueberries and the like grow wild is strongly acid. If roses and bluegrass are doing well, it probably is not.

Acidity and nutrients can be measured accurately only on samples in the laboratory. I suggest that field tests be made for acidity only, but if you have some flair for chemistry you can try the tests for nutrients.

Most upland soils in humid forested regions are likely to be too acid for vegetables, a bit too acid for most flowers, and too low in plant nutrients for best growth. A generous application of fertilizers rich in phosphorus and potassium usually should be given at the start. But many shrubs and flowers and a few fruits demand an acid soil. Most of the flowers need medium rather than high fertility, and some of the herbs want even low fertility.

Until you get a representative sample of each kind of your soil tested for acidity and plant nutrients, you are working a great deal in the dark. Samples should be taken carefully to represent an even slice or core of the surface soil that is normally spaded, down to 5 to 8 inches, say, and of the soil beneath to about 20 inches. If the layers above 20 inches are strongly contrasting, it is better to have a separate sample of each. Samples of unlike soils, or of unlike horizons from the same soil, should not be mixed. Generally it is best to write to a laboratory before you collect the samples to meet any special requirements of the laboratory.

Contamination. In areas of disturbed soil, you need to be on the lookout for buried trash. Fragments of tar paper, concrete, and other rubbish should be removed. Any buried pieces of plaster or concrete are bad for acid-loving plants like azaleas and may cause chlorosis, or yellowing, of the leaves.

Commonly the worst places for buried materials are near the house, where shrubs and flowerbeds are needed. The excavations for basements usually are made somewhat larger than necessary so that after the walls are finished a V-shaped space is left just outside the wall. Careless builders allow rubbish to accumulate in this space and at the end simply cover it with a layer of topsoil. It should have been filled with soil and packed to protect the basement wall from accumulations of water. For plantings near the house it often is necessary therefore to remove a large amount of miscellaneous rubbish.

Other bad spots that your examination may uncover include old buried roadways or sidewalks and spots of oil-soaked soil. They must be dug up and removed.

The air drainage of the garden affects its frostiness. If the garden is relatively high on a slope, the cold air moves or drains away from it into the low ground, so that plants escape the late-spring and early-autumn frosts that kill plants in the low ground. The gardener in low ground thus cannot count on so long a growing season as his neighbors on high ground with good air drainage. Plants growing on muck soils on low ground are even more subject to frost damage than plants growing on mineral soils on low ground. When you estimate the frost-free days from the reports of the nearby weather station, you should take these local ground conditions into account.

Water should be available for all of the garden except the parts that have only naturalized wild plants entirely adapted to the natural soil. A dependable source of irrigation water is essential in dry regions; short periods of drought cause damage that nullifies much of the benefit from other good practices.

You can conserve soil water so that you need only a little if you prepare the soil properly, build terraces where they are helpful, and use mulches to protect the surface. But this little is often critical for carrying through fine plants in the kitchen garden and among the ornamentals.

Evergreens need watering during severe winter droughts as well as summer droughts.

In cities where the use of water for gardens may be regulated during dry spells, the resourceful home gardener may find a way to store some of the rainwater in a pond or cistern.

The light requirements of plants vary greatly. You need to study the place to determine the hours of sunshine for the various parts of it, remembering that under deciduous trees there is little shade in winter and early spring and heavy shade in summer.

Nearly all vegetables and fruits do best in full sun, although the salad crops need shade in warm sections. Tomatoes, one of the most important vegetables in a small garden, grow fairly well in half the normal sunshine. The moving shade of a tree is less harmful to sun-loving plants than the dead shade of a building.

Other plants prefer shade. A few fine ornamentals flourish in the continuous shade of the north side of a building. Several of the ornamentals do well with winter and spring sun and summer shade, as under an oak tree.

Some lawn grasses prefer full sun and others partial shade. Ivy or other ground cover is more satisfactory than grass in heavy shade.

Many ornamental plants that seem to wither in full sun are really injured by high soil temperatures. If good mulches keep their roots cool, they do all right in full sun. Ordinarily clematis is one of these. Azaleas prefer partial shade, but they may do well in the sun if kept well mulched with something like sawdust.

Some of the trouble with plants growing near trees and big shrubs that is commonly put down to shade is due to root competition.

Plants need protection from competing roots, wind, and animals.

Roots from a competing tree may be pruned by digging a trench along one side--or even more if the tree is growing normally. A steel barrier may be placed in the trench to whatever depth the roots penetrate, say 2 to 4 feet, as a permanent protection for flowerbeds, vegetables, and shrubs.

Plants vary in their reaction to the roots of other plants. Azaleas, for example, grow well among oak trees, but roses do not. Yet azaleas grow poorly in competition with elm or maple roots. In fact, lawns, flowerbeds, and fine shrubs do badly near elms, maples, cottonwoods, poplars, and willows, which are not for small gardens.

In very large gardens near a woods, some gardeners dig deep, open trenches as a protection against roots, but they are unsightly and dangerous.

Many failures due to competing roots are incorrectly laid to the soil or its shade. Even small plants can rob the others. Forsythia roots, for example, are very bad robbers, and so are those of American bittersweet. Some iris are bad. Unless the roots of strong growers are kept pruned, they take over in a mixed garden. Flowerbeds may be protected from grass roots with 4-inch steel barriers and from most shrub roots with 12-inch barriers.

Wind is a serious hazard in many parts of the country--hot winds in summer, cold winds in winter, or both. Usually windbreaks of ornamental trees, especially evergreens, can be planted if the soil is suitable and if water is available. Winds may be very destructive in a few places around the garden during the winter. Those spots can be identified by their barrenness of snow when the rest of the garden is covered with it. Mature shrubs often thrive in such places if moved into them, but little shrubs of the same kind perish.

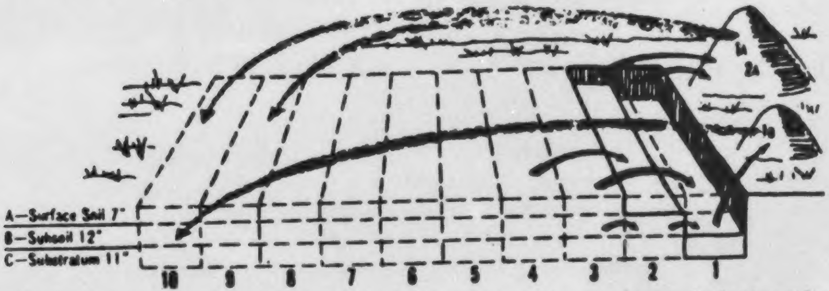
Animals are not useful in the garden. Kitchen gardens can be destroyed by rabbits. Dogs are probably the most commonly destructive in most home gardens. It is not worth while trying to grow fine flowering shrubs in some communities without fences.

Tillage is commonly the first step in preparing the garden soil. Organic matter, fertilizers, and other soil amendments are commonly mixed into the soil at the same time.

Large gardens can be plowed with machines, but small plots and small areas for flowerbeds and individual shrubs or trees should be spaded. Deep, fertile, granular soil, receptive to roots and water, may not have to be plowed or spaded very much, but usually some tillage is necessary.

The objectives of tillage are to produce and to maintain as deep a rooting zone of fertile granular soil as possible, control weeds, and keep the soil receptive to water.

The development and maintenance of good structure is the main reason for plowing and spading. Considering the soil most gardeners have, this means working a great deal of organic matter into the soil--not just once, but often.



Triple spading: 1A and 2A strips of surface soil are removed, and later moved to cover the last two strips at 9A and 10A; 1B strip of subsoil is removed, and added finally to 10B; 1C strip of substratum is spaded; 2B subsoil is spaded, mixed, and placed above 1C; 3A surface soil is put above moved subsoil in place of the original 1A.

Much has been said about the use of synthetic soil conditioners--polacrolytes. They do not bring about good structure when they are simply added to massive soil, but they help greatly to stabilize the granular structure of soil after such a structure has already been obtained by proper treatment, including tillage at the right moisture content.

For spading or stirring, a sample of the soil should just crumble in the hand after it has been formed into a ball and squeezed. Tillage of wet and sticky soils causes them to lose their granular structure and become massive, especially if they contain much clay and little organic matter. Once a clayey soil is badly puddled, it often takes years of careful handling to produce good structure.

It often is convenient to apply fertilizer and lime, besides organic matter, to the lower layers when spading. Most plant nutrients in time are carried down into the soil by rain and irrigation water if applied to the surface, but the movement is slow in clayey soils. Phosphorus especially moves down very slowly, although deeply rooted plants move it from their surface roots into their deep roots, where it becomes available to new plants after the old roots decompose.

Deep spading of the surface soil is rarely good practice in the garden except in the few soils that have little or no contrast between the horizons. The surface soil should be spaded to a depth of about 5 inches in dry sites and 7 or 8 inches in normally moist ones, without mixing in more than a very little of any lighter colored subsoil at any time.

Subsoil spading usually is necessary in most garden soils for good, deep rooting. That is, very many garden soils should be spaded to a considerable depth, but each major layer should be spaded separately and not mixed with the others. That is called double or triple spading if two or three layers are spaded separately.

Let us take as a common example a soil that has a dark-colored surface horizon of intermediate texture about 7 inches thick overlying a clayey subsoil that goes to 20 inches with a fairly pervious substratum below that.

Double spading is called for. You start spading at one end of the garden or flowerbed by removing entirely a 2- or 3-foot strip of surface soil to 7 inches and piling it to one side. Then you spade the subsoil for 13 inches--making a total depth from the surface of 20 inches--and mix in the necessary sawdust, compost, or manure (as organic matter to improve structure), any needed lime (to correct acidity), and the basic fertilizers. When you have spaded and prepared the subsoil in this first strip, you spade the surface soil from the next similar strip over it and at the same time mix the necessary organic matter and fertilizers into it. Then the newly uncovered subsoil is spaded as before--and so on across the entire bed or plot. The surface soil you remove from the first strip you carry over to cover the spaded subsoil in the last strip.

If the substratum below the subsoil is also massive and needs improvement for proper rooting and for proper movement of water, you carry out surface soil from the first two strips at the end of the plot and the subsoil from the first strip to one side.

Then the substratum is spaded and treated. The subsoil from the second strip is treated with organic matter and other materials, and you spade it over the freshly spaded substratum of the first strip. The surface soil from the third strip you place over the freshly spaded subsoil of the first strip. This triple spading is carried across the whole plot. The subsoil from the first strip is used in the last one and the surface soil from the first two strips covers the last two.

If the soil is massive, mere spading does little good: When it is wet again, the soil particles settle back together--deeper layers are heavily pressed by the weight of the ones above them.

Besides spading, you need to add abundant organic matter and the basic fertilizers for good structure and adequate nutrition of deep roots.

The organic matter has a direct effect in bringing about lines of weakness and preventing the settling of the soil particles into solid masses. But more important, in well-drained soils the organisms decompose the organic matter and produce compounds that lead to natural soil granulation.

These organisms need nutrients, especially nitrogen and phosphorus, which are deficient in sawdust, peat, and most organic materials (except high-quality compost and manure) that a gardener can add. The relation of nitrogen to organic matter I explain later.

Once the lower horizons are loosened thoroughly and supplied with organic matter and plant nutrients and if they are kept free of excess water by natural and artificial drainage, the roots of many kinds of plants extend down into them. The roots supply further organic matter to the lower layers.

If organic matter is not available, triple spading with good fertilization can be successful if the soil is planted immediately to a deep-rooted legume like sweetclover or kudzu. After a year or two of vigorous growth, these plants produce a large amount of organic matter above and below the surface. The aboveground part can be cut and spaded into the surface soil or mixed with other materials for the compost. Such treatments may delay the garden for a year or so, but they are often worthwhile.

The soil for small beds and little places for individual shrubs and trees can be improved in the same way. Each soil layer is removed and piled to one side separately. It is replaced after organic matter and fertilizers are added to it. If the soil has hardpans or very heavy claypans, it is best to discard those layers and replace them with good garden soil, with surface soil from a fertile field, or (for acid-loving plants) with soil from a woods.

Cultivation after the soil is spaded and during the growing season follows the same general rule about soil moisture. If the clayey soils are stirred or tramped when wet, they lose their granulation. If the garden must be walked on, broad boards should be laid down. Yet garden soils should be kept free of weeds and porous to water. Since so many of our rains in the United States come as sharp showers, a hard crust on the surface allows much of the water to run off and be lost before the soil becomes permeable. Then, too, after plants have fair size, surface tillage needs to be shallow and gentle so as not to harm surface roots. A good mulch can go a long way in substituting for tillage--it helps prevent crusting, promotes the entry of water, and suppresses weeds.

Organic matter is a vital material of which most gardeners rarely have enough.

Organic matter has several functions in the garden soils--as food for microorganisms and tiny animals within the soil, as a source of plant nutrients, and as a mulch. It also improves soil structure.

Its promotion of granular structure aids root growth and the entrance of water and air into the soil, reduces crusting and losses of surface soil by blowing or washing, and increases the ability of the soil to hold both water and nutrients for use by plants. Mulches help to control temperature, to reduce evaporation losses, and to suppress weeds. (Mulches of coarse sand and small stones have some of the same effects, too.) Organic matter, especially manure or compost derived from a wide range of normally growing plants, furnishes the growing plants a balanced supply of slowly available nutrients, including the trace elements.

The living roots, micro-organisms, and small creatures, such as earthworms, are a part of the total organic matter in the soil. Besides them, the garden soil contains three general classes of organic matter--the fresh remains of plants, partly decomposed materials, and the more or less stable, dark-colored humus, which is slowly decomposed to water, carbon dioxide, and ash. During the decomposition of fresh materials, a vast number of intermediate organic compounds appear before the formation of humus. Some of them are toxic in large amounts, but in normally well-drained soils they are transitory, and are themselves decomposed so soon that large amounts are never present. This decomposition is carried out by the tiny animals and the micro-organisms. The organic matter furnishes them food for growth and the nutrients in it are thereby released for use by plants.

The fresh materials vary widely in their rates of decomposition and in the amounts of plant nutrients they release, especially the amounts of nitrogen.

Cottonseed meal and meat scraps, for example, decompose rapidly and furnish so much nitrogen that they are regarded primarily as fertilizers. Next come freshly cut clover and grass. Wheat straw decomposes moderately fast but is low in protein and so furnishes little nitrogen. Oak leaves and pine needles are even more resistant. Finally, sawdust and wood chips decompose very slowly and furnish negligible amounts of plant nutrients to the soil. Because they decompose slowly they are good mulches, especially in warm, moist regions. As we shall see in a moment, dry straw, tree leaves, and sawdust actually reduce the nitrogen available to plants when first added to the soil.

Among the partly decomposed materials, animal manure is important. Nearly pure manure is also a kind of fertilizer; often it is dried and sold in bags. It decomposes rapidly and gives the soil a balanced supply of plant nutrients. Manure that has much dry straw and wood chips with it decomposes more slowly.

Leaf mold, the partially decomposed leaves just above the mineral soil in the woods, is an excellent material, especially for mulching acid-loving plants. It decomposes slowly and furnishes some nutrients. Most peats decompose slowly and furnish minor supplies of nutrients.

Compost is a major source of organic matter to the gardener who has trees. It can be used as a slowly available source of nutrients and as a mulch and to improve the structure of soils.

The chief aim in composting is to produce an organic matter approximately like that in a fertile soil, in which the organic matter has about 10 parts of carbon for each part of nitrogen, or, as we say, a C/N ratio of 10.

The plant materials most commonly available to the gardener--autumn leaves and straw or other plant stems--are dry, coarse, and much higher in carbon, with a C/N ratio of 30 or higher. If they are added directly, it is hard to mix them evenly with the soil, considerable moisture is needed to moisten them in advance of decomposition, and the excess carbon as carbohydrate furnishes the bacteria a great deal of energy food. With this food, which acts like sugar, they increase enormously in numbers, taking out of the soil phosphorus and nitrogen, which otherwise would be available to plants.

For a field or a very large garden, it is most practical to add these materials directly to the surface soil, together with enough nitrogen and phosphorus to balance the carbohydrate, and plow all of it into the soil. But for small gardens and flower beds it is best to arrange for partial decomposition in advance in a compost pile. The product can be added as needed in preparing beds or as a mulch.

You should have a rick or open bin in which to make the compost. You can use ordinary wire fence or boards attached to solid posts, or open brickwork, to make such a rick some 3 to 8 feet high and 3 to 5 feet wide and of any convient length. One end should be made with removable sides for convenience in building up the compost and for taking out the material.

Material like autumn leaves can be laid down in layers some 6 to 12 inches thick. To each layer is added some nitrogen and phosphorus (and magnesium sulfate--or epsom salt--in the humid East, or dolomitic limestone, if none of the compost is to be used for acid-loving plants) and a half-inch layer of soil.

The leaves should be moistened as they are added. The pile is built up in this way, layer after layer, and finally topped with a 1- to 2-inch layer of garden soil.

As it is built up, the material should be packed with the feet around the margins but only lightly in the middle--so that the center will settle more than the margins and water added to the surface will gradually moisten the whole.

Some gardeners use pits, but it is better to build from the surface of level ground. The material needs to be moist but not soggy. Decomposition without air leads to loss of nitrogen.

If lime is needed in compost intended for the kitchen garden, wood ashes can be used instead. If nitrogen and phosphorus are not available separately, a mixed fertilizer can be used. If considerable manure or fresh clover hay is used, the amounts of nitrogen and phosphorus can be reduced proportionately.

The table suggests some alternative mixtures in making compost with leaves or straw as the main material.

Material To Add in Making Compost

Material	Rate in cups per tightly packed bushel
For Genral Purposes, Including Acid-loving Shrubs:	
Combination A:	
Ammonium sulfate	1
Superphosphate (20 percent)	1/2
Epsom salt	1/16
Combination B:	
Mixed fertilizer 10-6-4	1 1/2
or	
Mixed fertilizer 5-10-5	2 1/2
For Kitchen Garden or Flowers Not Requiring Acid Soil:	
Combination C:	
Ammonium sulfate	1
Superphosphate (20 percent)	1/2
Ground dolomitic limestone or wood ashes	2/3
Combination D:	
Like B, above, plus ground dolomitic limestone or wood ashes	2/3

After 2 or 3 months of moderate to warm weather, the pile should be turned for best results, although that is not entirely necessary. In turning into another rick, you can cut down vertical sections in the old one and put them horizontally in the new one, being careful to keep any dry materials to the inside.

In regions having cool, frosty winters, compost made from autumn leaves in November and December may be turned the following May or June.

A pile that is made too large may overheat, with a loss of nitrogen.

If the material is kept reasonably moist and has a cap of garden soil (besides the soil between the layers), it should have no odor.

Applications of good compost or stable manure to the garden are about 4 to 40 bushels to 1,000 square feet.

Other organic materials may be used as mulches. Straw free of weed seeds is good, especially for small fruits, although it is a fire hazard and does not look neat in a garden.

Sawdust and wood chips are useful to mix into clayey soils to improve their structure and as mulches. Since they contain some slowly soluble carbohydrates, nitrogen must be added with them over and above that recommended for the soil otherwise. About 1 or 2 cupfuls of ammonium sulfate is used for each bushel. Perhaps well-rotted sawdust is somewhat better, but fresh sawdust is used successfully. When moistened, it gives nearly ideal acidity for azaleas and other acid-loving plants. For the kitchen garden and the rose garden it is well to use about one-fourth to one-half cupful of finely ground dolomitic limestone with each bushel.

A 3- to 5-inch mulch of sawdust is recommended around shrubs and other tall plants. Gardeners particular about the appearance of their intimate gardens can put a light covering of well-rotted compost over the sawdust or wood chips.

Cover crops are helpful on garden soils used for annual plants, both flowers and vegetables. Winter wheat, rye, ryegrass, or other winter-hardy crops may be planted in autumn. They protect the soil and absorb nutrients that would otherwise be lost. In the spring you have a supply of succulent, nutrient-rich organic matter to spade into the surface. This is very fresh organic matter and makes little contribution to the basic supply of humus.

The control of water is essential for the garden except in spots naturalized to wild plants that can endure wet, dry, or alternately wet and dry conditions.

Most soils lose a part of the water that falls on them through runoff from the surface, percolation through the soil, evaporation from the surface, and transpiration through plants.

Much of a gardener's success depends upon keeping these losses to a minimum, except the transpiration from his wanted plant, and on being sure that excess water does not accumulate in the pore spaces of the soil at the expense of air. Actually, it is not the excess water that injures plants in poorly drained soils, but the lack of air.

The ideal garden soil admits nearly all the water that falls on it, holds a large quantity within the fine capillaries between rains, allows any excess to drain away, is protected by surface mulches from excessive evaporation, and has no weeds. It should be added that a sandy garden soil subject to heavy leaching during the cool, rainy periods should have a cover of growing plants that take in nutrients that would otherwise be leached away. These are returned to the surface soil again when the plants are spaded under in the spring or the material can be taken to the compost pile.

Terraces are needed on sloping soils. To make full use of the water that falls during sharp showers, we need to have the soil granular. But in addition, on sloping soils, little, winding terraces, usually at a slight angle to the contour, to slow down the water are necessary. You can make several individual level terraces out of small stones the size of quart cans or gallon jugs with low walls on the downslope side of each large plant or small group of plants. These stones guide the water into the soil. With terraces, most of the plants can thus be planted or set out on level ground.

Drainage of wet soils can be accomplished in several ways. The simplest method is to throw up beds of soil above the original ground level, with places between for the excess water to collect and to flow away.

Irrigation is needed to some degree in most gardens. In fact, the more we do to improve our soils and to protect our plants, the more important it becomes to provide water for the critical periods so that we do not lose the benefit from all our other work.

A soil in good tilth, properly fertilized and well mulched, requires much less irrigation than a poorly managed one. Yet critical periods are fairly common when even the best garden soil needs water for fine plants.

Most of us irrigate when we see that our plants have started to wilt. That is too late for best results. When plants wilt, at least some damage has already been done. For a few dollars you can buy an instrument (called a tensiometer) to keep in your garden soil during the summer. Such an instrument indicates the moisture content and tells you when to irrigate before plants begin to wilt.

Depending on convenience, you may irrigate in small ditches, with a porous hose, or by sprays. The important thing is to irrigate well when it is done.

Excess salts can do a lot of harm. They are commonly associated with poor drainage in arid and semiarid regions, or with the use of salty irrigation water, or both. Readers having this kind of problem in their gardens are referred to the special chapter on the reclamation and management of saline and alkaline soils.

Controlling the reaction of the garden soil is one of the important adjustments the gardener can make for his plants. Many plants grow quite well over a wide range of soil reaction (acid-neutral-alkaline), especially when other growing conditions are good, but most plants do best within a rather narrow range.

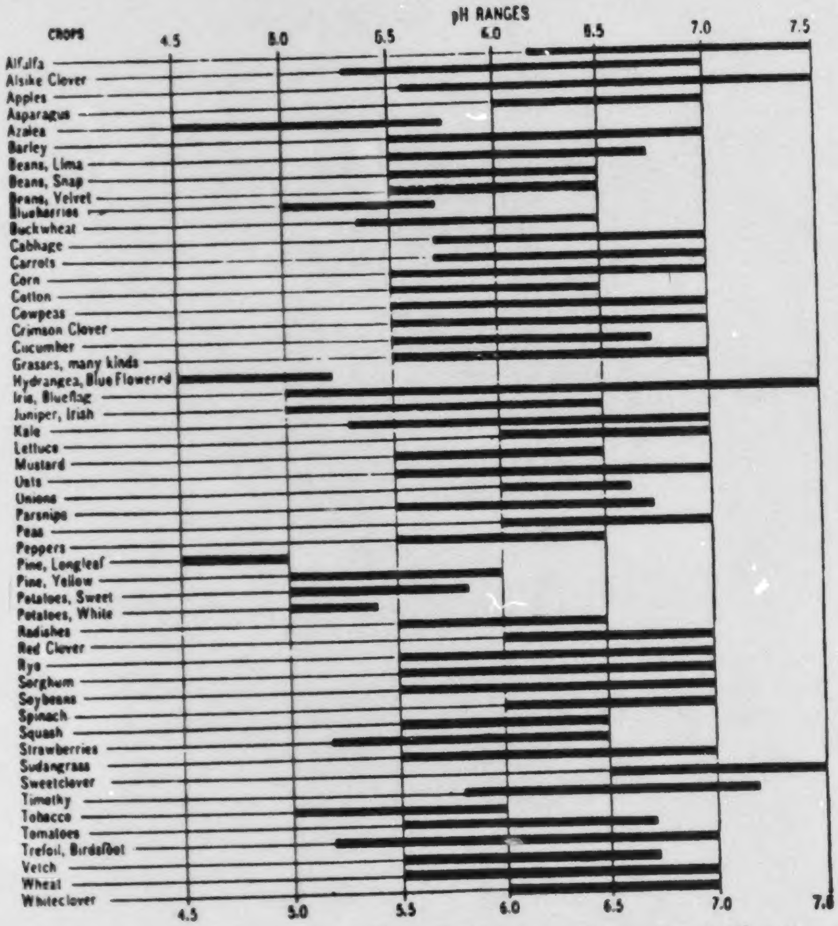
The garden vegetables, most of the common annual flowers, most lawn grasses, and many herbaceous perennials and shrubs do best in slightly to very slightly acid soil--about pH 6.1 to 6.9. The term "pH" is a quantitative measure of the degree of acidity:

	pH
Extremely acid	Below 4.5.
Very strongly acid	4.5-5.0.
Strongly acid	5.1-5.5.
Medium acid	5.6-6.0.
Slightly acid	6.1-6.5.
Neutral	6.6-7.3.
Mildly alkaline	7.4-7.8.
Moderately alkaline	7.9-8.4.
Strongly alkaline	8.5-9.0.
Very strongly alkaline	9.1 and higher.

A more acid soil than pH 6.5 is better for many plants, especially those that grow naturally under a forest with acid leaf litter. A few examples are given in the table and more are listed in my book, Our Garden Soils.

Any plants like these having an ideal soil pH range so far on the acid side usually do better in soil that has no free lime within the rooting zone. Such free lime occurs naturally in some soils, especially in subhumid and semiarid regions. It may have been added accidentally as ashes or in rubbish. Or it may have been added when garden soils were treated to make them best for vegetables, lawns, or other plants intolerant of strong acidity.

Other things being equal, such as structure, moisture, or organic matter, the micro-organisms that decompose organic matter, that transform organic nitrogen into forms most suitable to plant roots, and that fix nitrogen from the air grow best about pH 6.5. Near this same soil pH, 6.5, conditions are best for the availability to plants, without toxic amounts, of most plant nutrients.



Suitable pH Ranges for Various Crops and Ornamental Plants

Among the trace elements, iron, manganese, copper, and zinc become less available as the pH rises. Iron chlorosis, a yellowing disease of plant leaves due to iron deficiency, is a common symtom of acid-loving plants growing on soils containing free lime.

On the other hand, availability of nearly all important plant nutrients except iron diminishes with increasing acidity, phosphorus especially.

Most upland soils developed under forests in the humid sections are too acid for the best growth of lawns, vegetables, and many other plants. They require liming. Most soils developed under grass and shrubs in the subhumid or dry sections do not need lime.

Since pH measures only the intensity of soil acidity, and not the total amount, applications of lime for soils of the same pH increase with increasing total amounts of clay, with increasing activity of the clay, and with increasing amounts of organic matter.

The table overleaf gives some general guidelines for the application of finely ground limestone, all of which passes through a 100-mesh screen. Only one-half as much burned lime should be used. If the organic matter in the soil is very high, the amounts should be increased about one-fourth over those given in the table. If the organic matter is very low, the amounts of lime should be reduced by about one-fourth.

Suggested Applications of Finely Ground Limestone to Raise the pH of a 7-inch Layer of Several Textural Classes of Acid Soils, in Pounds per 1,000 Square Feet

	pH 4.5 to 5.5		pH 5.5 to 6.5	
Textural class	Northern and Central States	Southern Coastal States	Northern and Central States	Southern Coastal States
Sands and loamy sands ..	25	15	30	20
Sandy loams	45	25	55	35
Loams	60	40	85	50
Silt loams	80	60	105	75
Clay loams	100	80	120	100
Muck	200	175	225	200

You should bear in mind that the individual horizons of your soil may have quite different pH values and lime requirements. For example, many soils are medium acid in the surface, strongly acid in the subsoil, and only slightly acid or even slightly alkaline in the substratum.

Overliming must be avoided. It is easy to overlime very fertile soils in which only small amounts are required to make a big change. Overliming causes problems of nutrient deficiency, especially with the trace elements. Partly for this reason it is better to use burned lime or hydrated lime, both of which are strong. Any unevenness in spreading may lead to overliming.

The best material of all is finely ground dolomitic limestone. It contains magnesium carbonate and calcium carbonate. Most soils needing lime are likely to be deficient to some degree in both magnesium and calcium as plant nutrients. Furthermore, because dolomitic limestone becomes nearly insoluble at pH 7 or higher, the danger of overliming with uneven spreading is greatly reduced. Finally, if a very strongly acid soil is to be used for vegetables or lawns, it is better to raise the pH in two applications a year or so apart than in one big application.

For the acid-loving plants, you may have the problem of increasing the acidity of the soil. If the soil contains free lime, the most practical thing to do is to remove it, say to about 20 inches for rhododendrons and azaleas, and replace it with naturally acid surface soil from the woods. But for soils containing little or no free lime, sulfur can be added according to the amount shown in the table below.

Amounts for sandy loams are intermediate between those for sand and loam. It is not commonly practical to use soils more clayey than loam for acid-loving plants. The gardener can grow acid-loving plants by removing the clayey soil and replacing all or a part of it with sandy soil mixed with acid organic matter.

Although aluminum sulfate often is recommended to gardeners for increasing the acidity of the soil, it has a toxic salt effect on plants if it is used in large amounts. Small amounts are not very effective. About 7 pounds of aluminum sulfate is required to accomplish the same effect as 1 pound of sulfur.

Suggested Application of Ordinary Powdered Sulfur to Reduce the pH of an 8-inch Layer of Soil, as Indicated in Pints per 100 Square Feet

Original pH of soil	Pints of sulfur for 100 square feet to reach pH of --									
	4.5		5.0		5.5		6.0		6.5	
	Sand	Loam	Sand	Loam	Sand	Loam	Sand	Loam	Sand	Loam
5.0	2/3	2	....	....	....	....	....	....	....	....
5.5	1 1/3	4	2/3	2	....	....	....	....	....	....
6.0	2	5 1/2	1 1/3	4	2/3	2	....	....	....	....
6.5	2 1/2	8	2	5 1/2	1 1/3	4	2/3	2	....	....
7.0	3	10	2 1/2	8	2	5 1/2	1 1/3	4	2/3	2

The soil to be treated must be well drained. A mixture of sulfur and organic matter in wet soils produces hydrogen sulfide, an ill-smelling substance that is toxic to plants.

Whenever possible, it is best to prepare the soil at the proper pH for acid-loving plants in advance. The soil can be kept moist while the reactions take place, followed by a thorough moistening to leach out any soluble materials before planting. If the plants are already established before you discover that the soil is not acid enough, you can mix one-half to 1 tablespoonful of sulfur into the surface soil just above the roots for an area of about 1 square foot.

Besides sulfur, the use of acid mulches (such as pine needles, sawdust, and acid peat) and the continued use of ammonium sulfate as a nitrogen fertilizer tend to increase soil acidity.

A balance of plant nutrients in the soil is essential for good growth. Most gardeners realize this and may tend to oversimplify the problem of soil productivity by getting a big bag of fertilizer from the store, spreading it on the soil, and then feel they have done the job. That can be helpful, but the plant nutrients are no more important than proper structure, adequate supplies of water, and the control of soil temperature with mulches.

Besides the carbon, oxygen, and hydrogen from air and water, plants take at least 12 essential elements from the soil. Deficiencies in nitrogen, phosphorus, and potassium are most widespread; those elements are most commonly contained in mixed fertilizers. Calcium and magnesium ordinarily are included in liming materials, and at least small amounts are in most mixed fertilizers. Sulfur is abundant in most arid soils; it is contained in some fertilizers; and enough falls in the rain near cities. Six trace elements are needed by plants in tiny amounts: Iron, boron, manganese, copper, zinc, and molybdenum. Each of the 12 elements is important as a fertilizer somewhere in the world.

Vanadium and chlorine also are essential to plants, but we would not expect them to limit plant growth in garden soils. Occasionally, however, a soil may be found that contains toxic amounts of some of these trace elements or of others.

Each of the 12 elements is contained in manure and in compost made from normally growing plants, although usually not in the best proportions to make a good garden soil from a naturally infertile one. It would take a long time to build up the phosphorus content of a highly phosphorus deficient soil with compost and manure alone. It is more practical to use chemical fertilizer in addition to organic matter.

With the general scarcity of good manure and good compost and the general use of mixed fertilizers rich in nitrogen, phosphorus, and potassium, gardeners must pay increasing attention to the trace elements in order to have a proper balance among the nutrients at a high level of fertility.

The balance among the nutrients--not only the total amounts of them--is important. In many of the naturally infertile, leached soils of the eastern part of the country, for example, a lack of boron may be the factor that limits plant growth. Unless it is added, the gardener does not get the advantage of other fertilizers and good practices. Boron is especially important for tomatoes and other plants in the kitchen garden. Zinc also is rather commonly deficient; white streaks on the leaves of sweet corn indicate its lack.

The common basic elements, especially calcium, magnesium, and potassium, must be in proper relationship to one another for good nutrition.

Thus the use of a large amount of a pure calcium liming material can bring on magnesium deficiency, often exhibited by a chlorosis, or yellowing, of the older leaves, which spreads to the younger leaves. An excess of either magnesium or potassium can depress the intake of the other by plants.

Phosphorus, potassium, and nitrogen need to be in reasonable balance. An excess of nitrogen causes spindly, flabby plants susceptible to disease. Where gardeners use a lot of manure or compost and fertilizers rich in nitrogen, they are inclined to have big plants with lots of leaves and relatively few flowers and fruits. The addition of potassium to such a soil strengthens the plant. The addition of phosphorus encourages more fruiting, earliness, and root growth.

An excess of both phosphorus and nitrogen together, and especially where potassium is low, may stimulate iron deficiency, which causes chlorosis. This, of course, is especially bad for acid-loving plants if the soil pH is too high anyway.

Chlorosis can also be caused by manganese deficiency and by zinc deficiency, but it is most commonly due to either iron deficiency or magnesium deficiency. In the latter, the old leaves turn yellow early, and the yellowing spreads to the new leaves. With iron deficiency, the yellowing starts with the young leaves and progresses to the old ones. A nitrogen deficiency also can cause grayish or yellowish leaves, which tend to mature abnormally yearly.

The serious gardener finds it well worth his time to become familiar with the functions of the individual nutrients in plants and their common reactions in the soil, as explained in other chapters.

Estimating the amounts of fertilizer to apply depends upon three separate sets of more basic estimates: The nutrients already in the soil, plus those normally added in any compost or manure; the general requirements of the specific plants to be grown; and the amounts of the nutrients contained in the various fertilizer materials available for use.

None of the fertilizers consists 100 percent of plant nutrients. The actual plant nutrients are parts of other compounds, and some other materials may have been added to keep the fertilizer in good physical condition. Thus, if you use ordinary superphosphate as a source of phosphorus and 20 pounds of phosphoric oxide are called for, you would apply 100 pounds of the material, because ordinary superphosphate has only 20 percent of phosphoric oxide.

Our calculations are further complicated by the old trade practice of expressing the amounts of phosphorus in terms of phosphoric oxide (P_2O_5) rather than as elemental phosphorus (P). Similarly, the plant nutrient content of a potassium fertilizer is expressed as potash (K_2O), rather than as potassium (K). I hope that these practices will be changed, so that all nutrients are shown as the elements. That is now done with nitrogen (N).

A laboratory soil test is the best means for estimating the existing supplies of available plant nutrients, along with the appearance and abundance of previous plant growth. But these results cannot be followed blindly since the same test result indicates somewhat different fertilizer recommendations for different soils in the various parts of the country. A qualified soil-testing laboratory takes these factors into account in the interpretation of their tests. Thus when you send samples to the laboratory for testing, the more precise the information about previous plant growth and about the soil that you furnish the laboratory, the better the recommendations you receive from the laboratory.

Suggestions about the needs of specific kinds of plants for normal growth are given elsewhere in this book.

The following suggestions about groups of garden plants are given as rough general guides. Readers should be aware that individual plants within these groups vary considerably. After each group of plants, I indicate roughly their fertility requirements for nitrogen, phosphorus, and potassium as high, low, or medium.

Vegetables	High.
Herbs	Medium to low.
Lawn grasses	Medium to high.
Fruits	Medium.
Annual flowers	Medium.
Perennial flowers	Medium to low.
Shrubs, deciduous	Medium to low.
Shrubs, evergreen	Low.
Shade trees, deciduous	Medium to low.
Shade trees, evergreen	Low.

The table on page 161 is designed as a rough guide to the amounts of nitrogen, phosphorus, and potassium to use on garden soils of various textures and of low or high fertility, as indicated by present plant growth or soil tests. The figures I give are not for the fertilizers themselves; they refer to the net plant nutrients in fertilizers as nitrogen, phosphoric oxide, and potash. The high part of the range is for plants responding to high levels of fertility for the element, and the low range is for plants needing only low amounts of the element.

Suppose that our garden soil is a loam of low fertility and we want to prepare it for vegetables. As a general guide, we should need about 2 pounds of nitrogen, 3 of phosphoric oxide, and 2 of potash. That would amount to 20 pounds per 1,000 square feet of a 10-15-10 mixed fertilizer, containing 10 percent of nitrogen, 15 percent of phosphoric oxide, and 10 percent of potash. Instead of a 10-15-10, we could use 40 pounds of the more common 5-10-5, which would give us just what we need of nitrogen and potassium with a little extra phosphorus.

When preparing a garden soil for vegetables, flowers, and lawns, the necessary limestone and basic fertilizer, as suggested above, can be spread on the surface and spaded in along with about 10 to 20 bushels of manure or good compost for each 1,000 square feet. If the lower layers also need improvement, they may be given similar treatments with variations in the lime according to the degree of acidity.

Many gardens also need one or more of the trace elements, especially where little manure or compost is used.

Magnesium can be had with dolomitic limestone where it is used. Most mixed fertilizers contain some. If limestone is not used, as for acid-loving plants, ordinary epsom salt can be used at a rate of one-half cupful per 100 square feet for sandy soils and twice that for clayey soils.

For iron, gardeners have usually depended upon sprays having around 1 to 2 percent of iron as ferrous sulfate. One wants to be sure to use high-quality materials containing no residual acids. With woody plants, such spraying may need to be done every year to prevent chlorosis if the soil pH is too high or if it contains free lime. More effective iron fertilizers have appeared on the market under various trade names. They are some kind of iron chelates. Commonly they are added to the soil in water solutions, in accordance with the suggestions for the specific materials, although some spray them on the plants. But such spraying is not necessary except for curing an immediate situation. I have seen rather serious cases of iron chlorosis in azaleas cured within 10 days after treatment of the soil directly under the plant with an iron chelate dissolved in water.

Ordinary borax may be used to supply boron, which often is important in the kitchen garden on soils that were originally acid. You must be careful to spread it evenly at low rates of about 5 ounces, or 1 tablespoonful, to 100 square feet for sandy soils, or up to 3 times that amount for clayey soils. Such small amounts can be spread more easily if they are mixed with the bulkier fertilizers or with sand. For safety, a whole garden and lawn can be given a light application every 2 or 3 years. Although celery, cauliflower, apples, beets, and tomatoes are especially sensitive to a deficiency of boron, beans are easily harmed by a slight excess of boron.

GENERAL SOIL CLASS		NUTRIENTS (Pounds per 1,000 square feet)		
TEXTURE	FERTILITY LEVEL	NITROGEN (N)	PHOSPHORIC OXIDE (P_2O_5)	POTASH (K_2O)
Sandy soils . . .	Low	1 to 4	2 to 5	1 to 4
	High	0 to 2	0 to 3	½ to 3
Loamy soils . . .	Low	1 to 4	2 to 5	1 to 4
	High	0 to 2	0 to 3	0 to 2
Clayey soils. . .	Low	1 to 4	3 to 6	2 to 5
	High	0 to 2	0 to 3	0 to 3
Muck soils . . .	Low	½ to 3	3 to 6	1 to 7
	High	0 to 2	1 to 4	0 to 3

To treat soils deficient in manganese you may use about a tablespoonful of manganese sulfate per 100 square feet. If plants are already suffering chlorosis from manganese deficiency, a 1- or 2-percent solution of manganese sulfate may be sprayed on the plants, as with iron.

Zinc deficiency is rather uncommon except with citrus, pecans, and sweet corn. All plants need at least a little. Where deficiencies are suspected, zinc sulfate may be sprayed or applied to the soil in the same amounts as recommended for manganese sulfate.

Copper deficiencies are most likely in newly developed peat soils or in old, highly leached sandy soils. Applications of copper sulfate should not exceed 1.5 teaspoonfuls on peat soil for 100 square feet.

Very old, leached soils may have too little molybdenum for growing clover in the lawn mixture. If you suspect such a deficiency you may use approximately one-half teaspoonful of sodium molybdate for each 100 square feet. Excessive amounts are toxic.

Sulfur is a limiting factor in parts of the Pacific Northwest, the northern Lake States, and some of the highlands of the Middle Atlantic States far from cities or industrial establishments. If ordinary superphosphate is used, either directly or in low-analysis mixed fertilizers, sufficient sulfur is obtained that way. If a deficiency is known or suspected, it may be overcome by the use of ordinary powdered sulfur at the rate of about 1 cupful for 100 square feet. Certainly it is not needed on many gardens.

The trade offers to gardeners a few special mixed fertilizers to supply the minor nutrients. Those from dependable companies are good to use if you are sure that none of the nutrients is already present in excessive amounts.

The amounts of fertilizer materials I have discussed so far are based upon broadcast applications over an area. Once the soil for the kitchen garden is well built up in fertility--especially in calcium, magnesium, phosphorus, potassium, and the trace elements--it is usual to place the fertilizer in bands about 1.5 inches beneath and to one side of the seeds. You may dig a V-shaped trench on each side of the guide line for the row and add the fertilizer. These little trenches may be filled, and a shallow one made for the seeds themselves directly on the line for the row. Similar local placement can be made in bands around individual tomato plants, cabbages, and others. For such local placement, the recommended amounts of fertilizers are reduced by about half.

With high applications of compost or manure, the broadcast treatments may also be reduced by about half.

With sweet corn, tomatoes, and long-season salad crops, especially in gardens below the 42d parallel, it is helpful to give the plants additional nitrogen after they are well started. With tomatoes, this is after the first set of fruit. The application on sweet corn should be made when the plants are about 24 inches high. Nitrogen fertilizer is added in a small band by the side of the plants within the surface inch or so of soil. One may use about three-fourths cupful of ammonium sulfate, or its equivalent in some other nitrogen fertilizer, for each 100 feet of row, with the rows about 2 feet apart. Slightly lower amounts are used for plants in narrower rows and slightly higher if they are in wider rows. For an individual tomato plant about 2 teaspoonfuls of ammonium sulfate can be mixed into the surface inch of soil in a circular band beginning 4 inches from the plant and extending to about 12 inches from it.

These recommendations are very generalized, but they may still seem a bit complicated to a few readers. Those in a hurry can treat the "average" kitchen garden or flowerbed (if there is an "average") with 1,000 pounds of manure and 20 pounds of a 10-10-10 fertilizer per 1,000 square feet and hope for fair success. This will not fit all plants.

Recommendations as to fertilizers in bulletins and those based on the results of soil tests from a reliable laboratory are usually given in terms of pounds per acre or pounds per 1,000 square feet. Since most gardeners do not have proper scales for weighing these materials, tables are given (next pages) to show how such recommendations may be converted into ordinary household measures--pints, cups, tablespoons, and teaspoons. The values are not precise but are near enough for applications in the ordinary garden. One pint is equivalent to 2 cups, or 32 tablespoons, or 96 teaspoons. Figures in the tables refer to level-full measures, except those marked s, which are slightly less than full, and those marked with h, which are slightly heaped.

A pint of water weighs 1.0427 pounds. So for materials having that same weight, one may convert directly from pounds to pints, although most of them are lighter than water. The common materials have been grouped according to their weight, and calculations were made on the assumption that materials are dry and loose and are scooped up without packing.

One table gives the equivalents for various groups of materials in volume measure for 100 square feet from recommendations given in pounds per acre or pounds per 1,000 square feet. The next table translates these volume measures per 100 square feet into volume measures required for rows or individual plants at different spacings.

Suppose, for example, the recommendations for 1,000 square feet of garden soil are 80 pounds of finely ground limestone, 28 pounds of ordinary superphosphate, 2 pounds of ammonium sulfate, and 6 ounces of borax. By finding the proper group in the first table, we find that these same recommendations become respectively 6 pints, 3 pints, 8 tablespoonfuls, and 1 tablespoonful for 100 square feet. In the other table we find that for tomato plants spaced 2.25 by 2.25 feet the rates for individual plants are, respectively, ½ cupful, 5 tablespoonfuls, 1 teaspoonful, and 1/6 teaspoonful, and thus we see that the materials are used at very different rates and how easily it would be to get an excess of nitrogen and borax.

Lawns are a special problem to many gardeners. The basic principles of good soil structure, drainage, irrigation, acidity, and plant nutrients apply to the garden soils used for lawns about as they do to those used for vegetables and flowers. The same may be said for light and root competition.

Somehow, gardeners have the notion that any space not used for flowers, shrubs, and trees around the home should be seeded to lawn grass. This does not hold. Grasses cannot be expected to do well in heavy shade amid competing tree roots. In areas of relatively mild winters, several other ground covers, such as periwinkle or English ivy, do better, both in the shade and on steep banks, provided that the growing ends are tipped into the soil to give a solid root mat. Where shade and much walking are both handicaps to grass, flagstones can well be laid.

Establishing a proper grade is the first step in developing a lawn. When building a house, it is best to scoop up any good surface soil and lay it aside. The materials excavated from a basement space should be carted away, except for those needed in the lower part of deep fills, say in holes or depressions. Even for such fills, heavy raw clays should be avoided because drainage is slow through them.

Following completion of the excavation, grade lines should be planned in even gentle slopes away from the house. The grade lines should allow for an addition of good surface soil or "topsoil" of 3 to 10 inches, depending on the character of the subsoil. If the subgrade material is soil of medium texture and can be worked into good structure rather easily, a thin topsoil of 3 to 4 inches is adequate, but if the subgrade material is nearly structureless, either single-grained sand or massive clay, a thick topsoil is called for.

Steeply sloping soils cannot be expected to support good lawns. Any steep slope should be broken up by some stone walls or terraces so that the actual lawn has even, gentle slopes.

If the garden area slopes upward at the back of the house, considerable excavation may be needed and combinations of walls and drainage outlets may have to be built so that all the water from the slope is intercepted and flows slowly away from the house without danger of flooding the house or of eroding the soil during heavy storms.

Many steep soils, especially in the relatively dry Western States, are not stable; during periods of prolonged rain, masses of soil tend to slide. Heavy stone retaining walls, well anchored back into the hill and with deep foundations, are necessary for safety. Such construction calls for the services of a skilled engineer familiar with soil stabilization and drainage.

In building a new home and garden in any wooded area, arrangements should be made to protect selected trees. Builders should not be permitted to destroy the nice oaks and other slow-growing trees that can be saved. It takes too long to replace them from small ones. Most of the rapidly growing trees are a nuisance in a small garden because their relatively shallow roots compete directly with the grass and with other garden plants.

Trees selected for saving should be protected against machines used during excavation and grading by heavy planks about 6 feet long placed vertically around the tree and bound to it with heavy wire around the planks. If the final grade line is much below the original one, the trees cannot be saved, of course. If the soil was originally poorly or imperfectly drained and the new cuttings for roadways suddenly change the soil to a well-drained one, the older trees will probably die because their surface roots will not be able to supply enough water. Younger trees may be saved by watering until new roots have grown more deeply.

Trees can endure significant additions of soil where the grade line is above the original ground line only if wells are built around them. More than a 6-inch layer is hazardous without such a well. Wells are built of brick or stone from the original soil surface to the top of the new grade. The upper rim of the well is made level and is flush with the new grade only on the upper side of the slope. Wells are about 6 feet in diameter for mature trees. If the new grade line is no more than about 16 inches above the original, the well alone is enough to aerate the roots while they are being reestablished. If the added soil is deeper than that, a layer of coarse rock fragments, covered with fine stones and topped with some gravel and sand, should be laid outside the well on the ground out to the tips of the branches before the new soil or soil material is added. With tile laid through the well into this coarse layer, the roots can get air during the several years needed for the trees to establish roots in the new situation.

Having prepared the subgrade in even, gentle slopes, it should be firmed so that fills will not settle after the lawn is established. If the material is acid, ground limestone should be added. It can be fertilized on the basis of a soil test, but usually 30 pounds of ordinary superphosphate and 10 pounds of potassium sulfate to 1,000 square feet will not be far wrong. Manure, compost, or other organic materials should be worked into the subgrade material if it is clayey or if the soil tends to become massive.

After the subgrade is well prepared, the topsoil, already saved or brought in from a fertile meadow, should be added and graded for the final surface. This soil should be limed if it is acid and fertilized according to need. Generally a rough fertilizer recommendation that applies to many lawns is 25 pounds of a 10-10-10 mixed fertilizer or 50 pounds of 5-10-5 to start; fertilizers having a higher amount of nitrogen may be applied after the grass is established, say 25 pounds of a 10-6-4 to 1,000 square feet. If one is sure that phosphorus and potassium already exist in the soil in adequate supply, a nitrogen fertilizer that becomes available slowly without "burning" the grass is best.

The soil needs to be firm and free of big air pockets, but not hard. Rolling the surface of clayey soils should be avoided because it promotes the formation of hard crusts.

Lawn grasses may be established by sodding the soil surface, by sprigging individual plants or plugs, or by seeding. General recommendations for kinds of grasses to use are given in Department of Agriculture Home and Garden Bulletin No. 51, BETTER LAWNS. Recommendations also can easily be had from your State agricultural experiment station.

Good weed-free sod is both expensive and hard to come by. Weeds in the lawn make a serious problem to many gardeners. It is far easier to keep them out and prevent them from going to seed than it is to eradicate them once they are established in the turf. So the careful gardener prefers sprigs and clean seed over weedy sod.

It is easier to use sod than seed on fairly steep slopes that are to be grassed. When sod is placed on such slopes, many flattish wooden stakes, about 1 to 2 inches wide and 6 inches long, should be driven through it until the tops are just flush with the surface of the sod. These hold the sod from slipping down the slope during wet periods before the grasses become rooted in the soil beneath.

In warm areas, grasses like Bermudagrass, St. Augustinegrass, and ZOYSIA can be set as plugs or sprigs or as small sods. Even in the Central States ZOYSIA is becoming more popular because of its vigorous growth and resistance to drought, heat, and disease, despite the fact that it remains brown during the winter. Plugs of this grass are commonly set out in late spring or mid-summer at 1-foot intervals in new lawns. It is well fertilized, watered and weeded while it is getting started. Once the whole soil is well covered, weeds have difficulty establishing themselves.

Lawns in cool areas can be seeded during the spring; but in warm areas early autumn is best so that roots become well established before periods of high heat. Grass seeds are sown most evenly with a machine, but good results can be had with hand broadcasting on a windless day if half is sown in strips laid out one way and the other half in strips laid out across the first ones.

The seed is lightly covered with hand raking and watered lightly with a gentle, fine spray. Only new grass seedings are watered frequently and lightly. Mature lawns should be watered deeply if they are watered at all.

On sloping soils where there is danger of heavy rains before the grass is established, coarsely woven cloth or erosion netting can be staked down over the newly seeded surface to protect it from washing. It is held by small wooden stakes driven down flush with the surface; both stakes and netting will rot away.

After establishing the lawn, if the gardener finds small depressions from soil settling, shallow ones may be filled gradually over a period of years by sifting one-half inch of good garden soil onto the established grass from time to time.

The established lawn needs continual care on most soils. Occasional applications of finely ground limestone may be needed to keep the reaction at about pH 6.5. More than this should not be used. If the soil has been fertilised well with phosphorus and potassium and if any other deficiencies have been corrected at the start, an annual application of a mixed fertilizer high in nitrogen is commonly used.

Most recommendations suggest an application of something like 20 or 25 pounds per 1,000 square feet of a 10-6-4 fertilizer in the spring. Unless it is applied carefully when the grass is dry and unless the application is followed by rain or thorough sprinkling, "burning" of the grass is likely. It is much better to split the applications into two or three lighter ones over an interval of some weeks. You can buy a slowly available but high-analysis nitrogen fertilizer that does not burn the grass but gives a slow, continuous supply to the plants throughout the growing season.

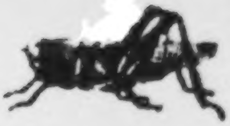
In warm, humid areas, however, spring applications of nitrogen often stimulate fungus diseases, especially on clayey soils. Bluegrass, for example, responds readily to nitrogen fertilizer. The plants are luscious and tender. Then during hot, humid days in late May or June, damping-off and brown patch may nearly destroy these susceptible plants. Under such conditions, the main application of fertilizer can be made in early autumn, after the danger of these diseases is past. The grass plants go into the winter with good root reserves and should be given only very light applications of nitrogen during the remainder of the year, except in the shade under the trees, where they should have light to medium applications in spring and summer.

Close clipping with the mower is a common cause of poor lawns, especially in warm places where the hot rays of the sun fall directly on the crowns of the plants. With the mower set high, the clipped plants can stand more heat. A mixture of clover helps to shade the crowns of bluegrass. In cool regions, the grass may be clipped down to 1 inch, but in warm areas 1.5 or 2 inches is better.

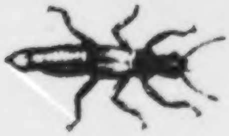
Frequently it is wise to leave the clippings on the lawn, because the clippings help to maintain organic matter and nutrients in the surface soil. Heavy clippings from infrequent mowings, however, should be removed to the compost pile and not left as a smothering mat over the grass.

ENTOMOLOGY

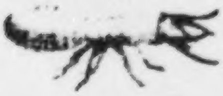
Insect Groups



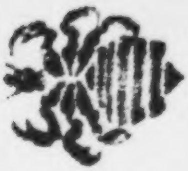
GRASSHOPPERS, ROACHES, AND THEIR KIN (Orthoptera) Medium to large insects. Live on land. Forewings leathery. Hindwings folded fan-like (some have no wings). Development gradual. Chewing mouth-parts.



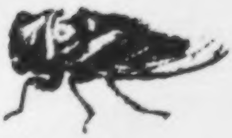
EARWIGS (Dermaptera) Small insects with typical pincer-like tail. Usually four small wings. Segmented antennae. Development gradual.



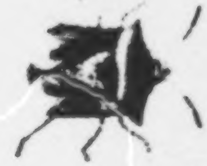
TERMITES (Isoptera) Ant-like insects, small and soft-bodied. Some have four long wings. Live in colonies. Specialized "castes" for working, fighting. Chewing mouth-parts. Development gradual.



LICE (Anoplura) Small, wingless insects with piercing and sucking mouth-parts. Body flattened. Legs with claws for clinging to warm-blooded animals.

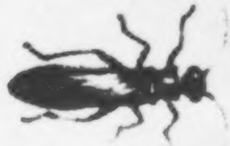


LEAFHOPPERS, APHIDS, AND SCALE INSECTS (Homoptera) Small to medium insects, most with two pairs of similar wings held sloping at sides of body. Jointed beak for sucking attached to base of head. Land insects. Some scale-like.



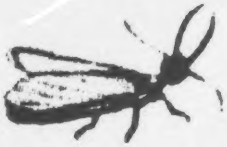
TRUE BUGS (Hemiptera) Range from small to large in size. Two pairs of wings, with forewings partly thickened. Jointed beak for sucking arises from front of head. Development is gradual.

DRAGONFLIES AND THEIR KIN (Odonata), Fairly large insects with two pairs of long, equal-sized wings. Body long and slender. Antennae short. Immature insects are aquatic. Development in three stages.

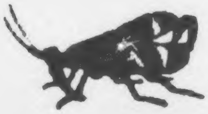


MAYFLIES (Ephemerida) **AND STONEFLIES** (Plecoptera) Both with two pairs of transparent, veined wings. In mayflies, hind wings are smaller; in stoneflies they are larger. Mayflies have long, 2- or 3-pronged tails.

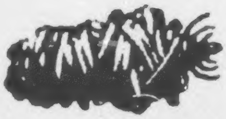
NERVE-WINGED INSECTS (Neuroptera) The two pairs of wings, usually equal in size, are netted with veins. Four stages of development: egg, larva, pupa, and adult. Chewing mouth-parts. Long antennae.



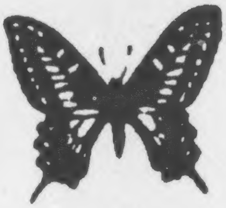
SCORPIONFLIES (Mecoptera) Small insects with two pairs of slender, generally spotted wings. Legs long. Antennae long also. Beak-like, chewing mouth-parts. Larvae live in soil.



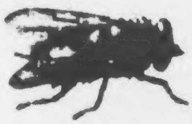
CADDISFLIES (Trichoptera) Most larvae live in fresh water. Some build ornamented case. Adults with two pairs of wings with long, silky hairs and with long antennae. Mouth-parts reduced.



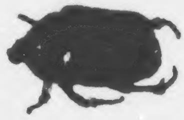
MOTHS AND BUTTERFLIES (Lepidoptera) Medium to large insects with two pairs of scaly wings. Sucking mouth-parts. Antennae knob-like or feathery. Development in four stages.



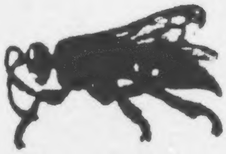
FLIES AND THEIR KIN (Diptera) Two-winged, small to medium insects, with sucking mouth-parts. Antennae small, eyes large. Second pair of wings reduced to balancing organs. Development in four stages.



BEETLES (Coleoptera) Forewings modified to thickened covers. Hind wings thin, folded. Size from small to large. Chewing mouth-parts. Antennae usually short. All have four life stages. Some aquatic.



BEES, WASPS, AND ANTS (Hymenoptera) Small to medium-size insects; many social or colonial. Two pairs of thin, transparent wings. Hindwings smaller. Mouth-parts for chewing or sucking. Only insects with "stingers." Development in four stages.



ERADICATION OF COMMON CROP PESTS

CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
CORN							
Armyworm	DDT	--	--	EC	1½ lb.	When larvae are young.	Do not feed forage, including ensilage, treated with DDT or toxaphene to dairy animals or animals being finished for slaughter. Parathion should be applied only by a trained operator.
	Parathion	1	12	EC	¼ lb.		
	Toxaphene	7	--	EC	1½-2 lb.		
Chinch bug Border rows	Dieldrin	0	60	EC	¼ lb.	To base of plants where bugs congregate; coat or wet bugs.	
	Toxaphene	7	--	EC	2 lb.		
Barrier strips	Dieldrin	0	60	EC	½ lb.	Strip 4 rods wide, half along edge of cornfield and half along edge of small grain, and strip across each end; repeat 1 or 2 weeks later if needed.	
Corn earworm	DDT	--	--	EC	2 lb. in 25 gal.	On larvae in whorl (bud-worm damage) 1 or 2 applications directed so spray will run into whorls of plant before tasseling and silking. On larvae in silks and ears (seed corn) use high-clearance sprayer having 4 nozzles per row; direct spray to ears. First application no later than 2 days after silks appear; repeat once or twice 2-3 days apart.	
	Sevin	5 kernels plus cob with husk removed 25 fodder or forage	1 7	WP	1½ lb. in 25 gal.		

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
CORN (con.)							
Corn rootworms	Aldrin	0	--	G, EC, or fertilizer mixture	1-2 lb.	Minimum dosage to row or hills when planting; maximum broadcast before planting and immediately work into upper 3-4 in. of soil. Apply diazinon to row only when planting.	Do not feed forage, including ensilage, treated with aldrin, DDT, or toxaphene, or with more than one application of endrin, to dairy animals, or that treated with DDT emulsion or dust to animals being finished for slaughter; do not feed forage treated with DDT granules within 90 days of slaughter, or with toxaphene granules to dairy animals or animals being finished for slaughter. Endrin and EPN should be applied only by a trained operator. Do not apply aldrin or dieldrin more than once. Do not apply heptachlor to soils where hops may be grown as it may adversely affect the hop plant.
	Diazinon*	0	--	G	1 lb.		
	Heptachlor	0	--	G, EC, or fertilizer mixture	1-2 lb.		
Cutworms and general soil insects	Aldrin	0	--	EC	1-2 lb.	Minimum dosage in band over row when planting; maximum broadcast before planting and immediately work into upper 3-4 in. of soil.	
	Heptachlor	0	--	EC	1-2 lb.		
European corn borer	DDT	--	--	EC D G	1½ lb. 2 lb. 1 lb.	When ½ of plants show first-generation larvae feeding in whorl and again 7 days later if needed. Treat for second generation when there are 100 egg masses per 100 plants.	
	Endrin	--	45	EC G	¼ lb. 1/5 - ¼ lb.		
	EPN	3	14	G WP	1/5 lb. ¼ lb.		
	Sevin	5 kernels plus cob with husk removed 25 fodder or forage	1 7	WP G	1½ lb. 1½ lb.		
	Toxaphene	7	--	G	1½-2 lb.		

*Use when rootworms have developed resistance to other insecticides.

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
CORN (con.)							
Fall armyworm Larvae in whorl	DDT	--	--	EC or G D	1-1½ lb.	One or two applications directed into whorls from above.	Do not feed forage, including ensilage, treated with aldrin, chlordane, DDT, or toxaphene, or with more than one application of endrin, to dairy animals, or that treated with DDT emulsion or dust to animals being finished for slaughter; do not feed forage treated with DDT granules within 90 days of slaughter. Endrin and parathion should be applied only by a trained operator. Do not apply aldrin or dieldrin more than once.
	Endrin	--	45	EC	3-4 oz.		
	Parathion	1	12	EC	¼ lb.		
	Sevin	5 kernels plus cob with husk removed 25 fodder or forage	1 7	WP	1½ lb. in 25 gal.		
	Toxaphene	7	--	EC D	1½-2 lb. 2 lb.		
Larvae attacking ears	DDT	--	--	EC	1½-2 lb.	One or two applications when larvae are young, directed at ear zone.	
	Sevin	5 kernels plus cob with husk removed 25 fodder or forage	1 7	D or WP	1½ lb.		
Flea beetles	Dieldrin	--	60	EC	1/3-½ lb.	When plants are small.	
Grasshoppers	Aldrin	0	21 (2 oz.) 30 (4 oz.)	EC	2-4 oz.	To hatching areas when nymphs are young.	
	Chlordane	0.3	--	EC	¾-1½ lb.		
	Dieldrin	--	60	EC	1-2 oz.		
	Malathion	2 kernels plus cob with husk removed 8 forage	5 5	EC	1 lb.		
	Sevin	5 kernels plus cob with husk removed	7	WP	½-1 lb.		
		25 fodder or forage	7	WP	½-1 lb.		
	Toxaphene	7	--	EC	1-1½ lb.		

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
CORN (con.)				Baits*	In 100 lb. bait		
Mormon cricket	Aldrin	0	--	EC or WP for wet bait; oil soln. for dry bait	2 oz.	Spread bait ahead of advancing band of crickets at 10-20 lb. per acre.	Store bait where livestock cannot reach it; do not pile on ground. Keep livestock off air strips where planes are being loaded with bait. Try not to spill bait; clean up any that is spilled. Do not feed forage, including ensilage, treated with aldrin, chlordane, endrin, or toxaphene to dairy animals or animals being finished for slaughter. Endrin and parathion should be applied only by a trained operator.
	Chlordane	--	--		½ lb.		
	Toxaphene	--	--		1 lb.		
Southwestern corn borer	Endrin	--	--	G	½ lb.	2 applications 10 days apart when second-generation borers are first observed.	
Spider mites	Parathion	1	12	D or EC	½ lb.	On foliage as needed.	
Sugarcane beetle	Aldrin	0	--	EC or G	1 lb.	6-8 in. band on top of row when planting. Aldrin may also be applied as soon as possible after corn comes up.	
	Heptachlor	0	--	EC or G	1 lb.		
Sugarcane borer	Endrin	--	--	G	½ lb.	3 times 10-14 days apart when second- or third-generation borers are first observed.	
White grubs	Aldrin	0	--	EC or G	1½-2 lb.	Broadcast 2-3 weeks before planting and immediately work into upper 3-4 in. of soil.	Do not apply heptachlor to soils where hops may be grown as it may adversely affect the hop plant.
	Heptachlor	0	--	EC or G	1½-2 lb.		
Wireworms	Aldrin	0	--	EC or G	1½-2 lb.	Broadcast before planting and immediately work into upper 3-4 in. of soil.	
	Heptachlor	0	--	EC or G	1½-2 lb.		

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* Prepare according to directions in FB 2081.

CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
RICE							
Grape colaspis	Aldrin	--	--	D or WP	½ lb./100 lb. seed	To seed before planting.	Do not use treated seed for food or feed.
Rice water weevil	Aldrin	--	--	D or WP	½ lb./100 lb. seed		
Stink bug	Malathion	8	7	EC	¾-1 lb.	About 1 week after heads appear. Two applications may be needed if infestation is severe.	Do not allow dairy animals or animals being finished for slaughter to graze on fields treated with toxaphene.
	Phosphamidon	--	21	EC	¼-½ lb.		
	Sevin	5 grain 100 straw	14	WP	1½-2 lb.		
SORGHUM							
Corn earworm on heads for grain	Phosdrin	1	3	EC	½ lb.	When larvae are small.	Do not feed forage or straw treated with toxaphene or phosphamidon to dairy animals, or animals being finished for slaughter. No limitation on use of the grain.
	Sevin	10 grain 100 forage	21 1	WP	1½ lb.		
Chinch bug Border rows	Dieldrin	0	60	EC	¼ lb.	To base of plants where bugs congregate; coat or wet bugs.	
	Toxaphene	5 grain	28	EC	2 lb.		
Barrier strips	Dieldrin	0	60	EC	½ lb.	Strip 4 rods wide, half along edge of sorghum field and half along edge of small grain, and strip across each end; repeat 1 or 2 weeks later if needed.	

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
SORGHUM (con.)							
Fall armyworm	DDT	--	--	EC D	1 lb. 2 lb.	When larvae are young.	Do not feed forage treated with DDT, or with more than 2 oz. of dieldrin, to dairy animals or animals being finished for slaughter. Do not apply DDT to sorghum after heads begin to form unless heads are being produced for seed. Do not apply endrin more than once. Endrin, parathion, and Phosdrin should be applied only by a trained operator. Do not feed forage treated with toxaphene to dairy animals or animals being finished for slaughter. Do not apply toxaphene more than once after heads begin to form.
	Endrin	--	45	EC	3-4 oz.		
	Parathion	1	12	EC	½ lb.		
	Sevin	10 grain 100 forage	21 1	WP	1½ lb.		
	Toxaphene	5	28	EC D	1½-2 lb. 2 lb.		
Larvae in whorl (budworm damage)	DDT	--	--	EC	2 lb.	To entire plant before heads appear.	
	Parathion	1	12	EC	½ lb.		
	Sevin	10 grain 100 forage	21 1	WP	1½ lb.		
Flea beetles	Dieldrin	--	--	EC	1/3-½ lb.	When plants are small.	
Grasshoppers	Dieldrin	0	40	EC	1-2 oz.	To hatching areas when nymphs are young. Apply dieldrin only once.	
	Toxaphene	5	28	EC	1-1½ lb.		
Sorghum midge on heads for seed	DDT	--	--	D	1½ lb.		
Sorghum webworm	Naled*	1	4	EC	1½ lb.	As soon as infestation is found.	
	Phosdrin	1	3	EC	½ lb.		
	Sevin	10 grain 100 forage	21 1	WP	1½ lb.		

* Recommended on grain sorghum only.

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
SMALL GRAINS-- Barley, Oats, Wheat, and Rye							Do not apply DDT after heads begin to form. Do not apply endrin more than once. Do not allow dairy animals or animals being finished for slaughter to graze on fields treated with DDT or toxaphene. Endrin or parathion should be applied only by a trained operator. Do not apply DDT to barley or parathion to rye. Do not apply demeton more than twice per season. Allow at least 14 days between applications.
Armyworm	DDT	--	--	EC	1½ lb.	When larvae are young.	
	Dieldrin	0.1 grain 0.75 straw	7 7	EC	¼ lb.		
	Parathion	1 (except on rye)	15	EC	¼ lb.		
	Toxaphene	5	--	EC	1½ lb.		
Brown wheat mite	Demeton	0.75 grain (except on rye) 5 forage and straw (except on rye)	45 21	EC	¼ lb.	When damage appears.	
	Parathion	1 (except on rye)	15	EC	½ lb.		
Chinch bugs Barrier strips	Dieldrin	0.1 grain 0.75 straw	7 7	EC	½ lb.	Strip 4 rods wide, half along edge of cornfield and half along edge of small grain, and strip across each end; repeat 1 or 2 weeks later if needed.	
Corn leaf aphid	Parathion	1 (except on rye)	15	EC	¼ lb.	On foliage as needed.	
Cutworms	DDT	--	--	EC	1½ lb.	When larvae are young.	
	Toxaphene	5	14 barley 7 others	EC	1½ lb.		
Fall armyworm	DDT	--	--	EC D	1 lb. 2 lb.		
	Endrin	--	45	EC	3-4 oz.		
	Parathion	1 (except on rye)	15	EC	¼ lb.		
	Toxaphene	5	--	EC D	1½-2 lb. 2 lb		

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
SMALL GRAINS-- Barley, Oats, Wheat, and Rye (con.)							
Grasshoppers	Aldrin	0.1 grain 0.75 straw	7 30	EC	2-4 oz.	To hatching areas when nymphs are young.	Do not apply chlordane after heads begin to form. Do not allow grazing on fields treated with chlordane. Do not allow dairy animals or animals being finished for slaughter to graze on fields treated with toxaphene. Methyl parathion or parathion should be applied only by a trained operator. Do not apply parathion to rye. Store bait where livestock can not reach it; do not pile on ground. Keep livestock off airstrips where planes are being loaded with bait. Try not to spill bait; clean up any that is spilled. Do not apply demeton more than twice per season. Allow at least 14 days between applications.
	Chlordane	--	--	EC	⅜-1½ lb.		
	Dieldrin	0.1 grain 0.75 straw	7 7	EC	1-2 oz.		
	Malathion	8	7	EC	1 lb.		
	Toxaphene	5	--	EC	1-1½ lb.		
Greenbug	Demeton	0.75 grain (except on rye) 5 forage and straw (except on rye)	45 21	EC	¼ lb.	When temperature is 50° F. or above.	
	Methyl parathion	0	15	EC	¼ lb.		
	Parathion	1 (except on rye)	15	EC	¼ lb.		
	Phosphamidon*	--	30	EC	¼-½ lb.		
				Baits **	In 100 lb. bait		
Mormon cricket	Aldrin	0.1 grain 0.75 straw	7 30	EC or WP for wet bait; oil soln. for dry bait	2 oz.	Spread bait ahead of advancing band of crickets at 10-20 lb. per acre.	
	Chlordane	--	--		½ lb.		
	Toxaphene	5	14 barley 7 others		1 lb.		
					Per colony		
Red harvester ant	Carbon disulfide	--	--	Fumigant	4 fl. oz.	Pour into entrance hole of nest.	
	Chlordane	--	--	5% D	½ lb.	Spread thinly in 4-6 in. band in circle 5-6 ft. in diameter around nest entrance.	
	Dieldrin	0.1 grain 0.75 straw	7 7	1.5 % D	⅛ lb.		

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*Recommended for use on wheat only.

**Prepare according to directions in FB 2081.

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CORN, RICE, SORGHUM, AND SMALL-GRAIN INSECTS (continued)

Crop and insect	Insecticide	Tolerance (p.p.m.)	Min. days from last application to harvest or feeding	Formulation	Dosage per acre (active ingredient unless otherwise indicated)	Where and when to apply	Safety restrictions
SMALL GRAINS-- Barley, Oats, Wheat, and Rye (con.)							
Winter grain mite	Malathion	8	7	EC	3/5 lb.	Apply as soon as injury appears.	Parathion should be applied only by a trained operator.
	Parathion	1 (except on rye)	15	EC	¼-½ lb. (Maximum for airplane application)		Do not apply parathion to rye.

Abbreviations:

Bait	B	Emulsifiable concentrate	EC	Spray	S
Dust	D	Granules	G	Wettable powder	WP
				Solution.	soln.

BEEF CATTLE

You can convert feeds produced on your farm into beef under a number of systems:

1. Beef breeding herd, with all calves except necessary replacements sold as feeders at weaning or at yearling ages. A variation of this system, more important in the South than elsewhere, is to sell fat calves for slaughter at weaning.

2. Beef breeding herd combined with feeding operation. All surplus young cattle fattened on the farm where produced.

3. Feedlot operations with purchased feeder cattle.

4. Combination grazing and feeding operations with purchased feeder cattle.

5. Dual-purpose breeding herd, with calves either fattened on farm where produced or sold to feeders.

The particular system of beef production that will suit your farm depends on--

- Type of farm. Should most of it be in pasture or forage production or is much or all of it suitable for grain production?
- Size of your farm.
- What markets are available in your area.
- Your financial situation.
- How much help is available and what you pay for it.

You can vary your feeding plan--the ratio of concentrates to roughage--to use your available feed to the best advantage. Table 1 gives reasonably realistic estimates of the amounts of feed required per head for various production programs.

Cow herds are particularly adapted to farms that produce large amounts of pasture and harvested roughage and limited amounts of grains. Drylot full feeding of weaned calves, either steers or heifers, requires no pasture--only moderate amounts of harvested roughage and relatively large amounts of grain.

TABLE 1.—*Approximate amount of feed required per head under various beef-production programs*[1]

Program	Pasture	Average per day			Average per year or per animal		
		Harvested roughage (hay equivalent)	Grain	Protein supplement	Harvested roughage (hay equivalent)	Grain	Protein supplement
1. 1,000-pound beef cow and calf to weaning (no creep):	*Days*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Pasture	215						
Winter lot, 150 days		20		1	3,000		150
2. Additional to creep-feed calf for 100 days			5			500	
3. Feeding steer calves from 450 to 950 pounds: Dry lot, 250 days (average daily gain, 2 pounds)		5	12	1.5	1,250	3,000	375
4. Feeding steer calves from 450 to 1,050 pounds:[2] Winter, 150 days (average daily gain, 1.5 pounds)		8	5	1	1,900	2,150	250
Pasture, 120 days (average daily gain, 1.5 pounds)	120						
Dry lot, 100 days (average daily gain, 2.0 pounds)		7	14	1			
5. Feeding heifer calves from 400 to 750 pounds: Dry lot, 200 days (average daily gain, 1.75 pounds)		4	11	1	800	2,200	200
6. Feeding yearling steers from 700 to 1,050 pounds: Dry lot, 150 days (average daily gain, 2.30 pounds)		7	13	1	1,050	1,950	150
7. Feeding 2-year-old steers from 950 to 1,200 pounds: Dry lot, about 100 days (average daily gain, 2.5 pounds)		10	15.8	1.1	1,000	1,580	110
8. 1,200-pound dual-purpose cow milked 250 days and her calf to weaning[3]	215				4,000	1,200	650

[1] This table is based largely on published data. Amounts are approximate and will differ in various sections of the Nation, particularly because of differences in the length of the grazing seasons.

[2] Deferred Kansas System.

[3] Assuming that the cow is milked 250 days and produces 6,500 pounds of milk. She is fed a 16-percent concentrate mixture at the rate of 1 pound for each 4 pounds of milk produced, and is fed a protein supplement during her dry period (winter).

Other feeding operations with older cattle and deferred feeding systems with calves effectively use larger proportions of roughage than calf feeding systems. These operations, however, also require grain production on the farm or a local source of grain at reasonable prices if they are to be successful.

Your farm may be best adapted to a system in which cattle are both raised and fattened. For example, part of your farm may be rough, broken, non-tillable land that is best suited for grazing cow herds. If your farm also has tillable land from which you can harvest grain and roughage, a system of fattening the animals raised as calves or yearlings may be your choice.

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Dual-purpose cattle systems were an important part of the Nation's cattle economy in earlier years. They have become less important with the trend toward larger farms, more specialization, more expensive labor, and more rigid sanitary requirements for the production of dairy products for human use.

Today, the dual-purpose cattle system probably is suitable only to small or medium-sized farms in areas where there is not a ready market for fluid milk and where unpaid family labor is available.

This bulletin discusses the management of beef-cow herds. Suggestions are included on raising the calves produced to market ages.

SIZE OF HERD AND EXPECTED PRODUCTION

On most farms, a beef herd is only one of several enterprises. Therefore, considerable flexibility in size of herd is possible.

The herd should include at least 20 to 25 cows. One bull can service a herd this size or somewhat larger. Small herds cost more per cow for bull service. Often, inferior bulls are used in small herds--and calf quality is lower.

Partnership or community ownership of bulls or use of artificial insemination may make smaller herds feasible. Artificial insemination is successful with beef cattle if the cows are observed carefully so that heat can be detected accurately, but it is not available in some areas.

The profit you can expect from your beef herd depends to a large extent on the percentage of the cows that produce calves each year. A survey in 1955 indicated that less than 80 percent of the Nation's beef cows produced calves each year. Properly managed farm herds should exceed this figure, but herds with average calf crops of above 95 percent over a period of years are exceptional. A calf crop of 90 percent is about the attainable average under good management.

Weaning weights vary with the type of cattle and feed supplies, but your calves should weigh an average of 450 to 500 pounds at 7½ to 8 months of age if you are to make money.

SELECTING BREEDING STOCK

Any of the leading beef breeds is satisfactory for farm production in areas where they are adapted. You can choose the breed you prefer.

Crossbred calves of British types have given conflicting results in limited experiments, but they probably are more vigorous and grow faster on the average than purebreds or grades with parents of similar quality. However, their superiority is not great, and it is difficult for a small-herd owner to follow a systematic crossbreeding program.

Unless you have a herd large enough to use two or more sires, you probably should use a bull of the same breed as your cows. This will involve a period of "grading up" if you start with a mixed or nondescript group of cows. In some areas, it is difficult to market crossbreds to advantage.

In the Deep South, experiments have shown that crosses between Brahman and British breeds exhibit vigor and growth rates superior to either parental type. They produce carcasses equal to or only slightly inferior to those from British-type cattle at least when marketed at young ages. The value of Brahman blood is particularly apparent in the cow's calf-raising ability. If you live in an area where some Brahman blood is desirable, you can use a continued crossbreeding program or grades or purebreds of one of the new breeds based on Brahman-British crossbred foundations.

More important than selecting the breed or the crossbreeding plan is selecting breeding stock from within the breed or breeds chosen.

SELECTING HERD BULLS

If you can find one, an older bull that has been proved on the basis of his progeny to be a superior breeding animal probably would be your "best buy," provided he is free of reproductive disease. Such bulls seldom are available, however, so you probably will be forced to purchase young, untried bulls.

A bull 12 to 14 months of age can be handbred to 20 to 25 cows in a season or can be allowed to pasturebreed smaller herds. Using bulls this age is risky, however, since their fertility and breeding behavior tend to be uncertain. It is preferable to use a bull at least 18 months old. Under pasture breeding conditions, bulls of this age and older usually will breed 25 to 30 cows satisfactorily in a 70- to 120-day breeding period.

Consider the following factors in selecting a young bull:

- He should be from a sire and dam with good fertility records. If possible, choose a bull from a sire and dam whose other offspring have above-average performance records.

- He should have been raised by his own mother and have had a satisfactory weaning weight. Such a bull will have a good chance of transmitting satisfactory calf-raising ability to his daughters and thus contribute to the longtime improvement of the herd's performance.

- He should have exhibited good gaining ability after weaning and should have a high weight-for-age at 12 to 14 months of age.

- He should be a thick-fleshed animal of desirable conformation, of acceptable breed character, and of an inherent skeletal size that is compatible with producing finished progency at popular market weights.

- He should be disease free and from a herd with a good health history.

SELECTING FEMALES

As far as possible, use the same standards when buying females for your herd as when buying bulls. Ordinarily, you cannot be so selective.

Cull the cow herd on the basis of regularity of calving and weight and quality of calves produced. If a cow's first calf is poor, her later calves are likely also to be below average. You can safely cull cows in the lower 10 to 25 percent of a herd on the basis of performance records of 1 or 2 of their calves.

For replacements in an established herd, 20 to 40 percent of the heifers raised must be saved if herd numbers are to be kept up (depending on percentage of calf crop, culling intensity among cows, and the age at which cows are replaced). Select heifers with heavy weaning weights, good rate of gain and fattening qualities, and acceptable beef-type conformation.

Keep performance records to help you cull older animals and select replacement animals intelligently. These records need not be elaborate but should include the following:

- Identification of each animal by means of ear tattoos, ear notches, brands, or neck straps.

- A record of the parentage of each calf.

- A record of the birth date of each calf.

- A weight and grade taken at or near weaning to evaluate the dam's maternal ability.

If you keep your calves past weaning age, you should feed and manage all those of each sex alike so that you can evaluate rate of gain from weights taken 6 months to a year after weaning. Grade animals at this time.

When buying herd sires or females from other herds, look for animals from herds where performance records are available. Because management practices and feed supplies have a great influence on records, do not rely solely on the absolute size of the records. Instead, select animals from among the tops in a herd.

RAISING REPLACEMENT BREEDING ANIMALS

Good pasture is the best and, usually, the cheapest feed for developing replacement heifers following weaning. However, heifers usually are weaned in the fall and must be fed through the winter in dry lot. The level of feeding to be used the first winter following weaning should depend largely on whether you plan to breed the heifers at 14 to 16 months of age to calve at about 2 years of age or whether you plan to breed them to calve first at about 3 years of age.

If you plan to breed them for early calving, feed them during the first winter so that they gain 1 to 1½ pounds per day and weigh 600 pounds or more at breeding.

Rations that should accomplish this are as follows:

		Pounds
1.	Corn or sorghum silage	25 to 30
	Grain	3 to 5
	Protein supplement	1
2.	Legume or mixed hay	12 to 15
	Grain	3 to 5
3.	Corn or sorghum silage	20 to 25
	Legume hay	3 to 4
	Grain	3 to 5
4.	High-quality grass hay	12 to 15
	Grain	3 to 5
	Protein supplement	1

These heifers will require similar rations during their second winter just before calving.

If you postpone breeding so that heifers drop their first calves as 3-year-olds, you can feed them more limited and economical winter rations and depend on summer pasture to produce most of the growth.

Rations that can be expected to produce gains of 1/4 to 3/4 pound daily during the first winter are:

		Pounds
1.	Legume hay	4 to 6
	Low-quality nonlegume roughage, such as straw, low-quality grass hay, or cottonseed hulls	6 to 8
2.	Corn or sorghum silage	20 to 25
	Cottonseed, soybean, or linseed meal, or other high-protein supplement	1

		Pounds
3.	High-quality grass hay	12 to 15
4.	Low-quality grass or legume hay	10 to 15
	Protein supplement	1
5.	Legume hay	3 to 5
	Corn or sorghum silage	6 to 10
	Grain	2 to 3

In many parts of the country you can winter heifers more cheaply on permanent pasture than in dry lot on harvested feed even if pastures are low in quality. Feed protein supplements at the rate of 1 to 2 pounds daily if you do this.

Usually, bulls should be fed rather liberally from weaning to 12 to 14 months of age. This promotes rapid development and makes breeding use possible at minimum ages. Also, liberal rations during this period give a bull an opportunity to show his inherent ability to gain, fatten, and develop satisfactory conformation. His ability in these respects is related to the potential performing ability of his progeny. Thus, selecting and using bulls with above-average performance during this period should lead to improved herd performance.

FEEDING AND CARING FOR BREEDING BULLS

As a general rule, a bull requires more feed than a cow. How much more depends on his size and age and how heavily you use him.

Fertility is likely to be best if bulls are kept in medium flesh and can exercise at will. Too much fat wastes feed and money and may result in poor fertility. Bulls that are too thin also may have breeding difficulties.

During the grazing season, good pasture will provide most of the bull's nutritional needs. Usually, however, young growing bulls need some supplementary grain to keep in satisfactory flesh. If used on a seasonal basis, most bulls are likely to lose 200 to 300 pounds during breeding season. They must gain 1 to 1½ pounds a day during the rest of the year to regain this loss.

Older bulls usually will maintain desirable condition on good pasture in summer and roughage in winter. To provide enough carotene, which the animal can convert to vitamin A, at least half of the roughage fed (dry basis) should be good legume hay or corn, sorghum, or grass silage. If none of the roughage is legume, 1 to 2 pounds daily of a high-protein supplement should be fed.

Although there is no scientific evidence to confirm their idea, many breeders think it is desirable to stop feeding silage about 30 days before the breeding season. Usually, some grain is fed for 30 to 60 days before the breeding season, and during the breeding season when this is possible, to improve breeding performance. One pound of protein supplement and 5 pounds of grain daily should be ample for most bulls. The condition of the bull should govern the amount of feed offered.

Do not allow the herd bull to run with the cows the whole year. If possible, keep him in a separate enclosure during the nonbreeding season. If you cannot keep him in a pasture by himself after the breeding season, pasture him with steers or pregnant cows. A bull in good breeding condition is likely to be temperamental. Always handle him with care.

The fence around the lot or corral where you keep the bull should not stop him from seeing other cattle but should be securely constructed. For an added safety factor, install a battery-operated "charged-wire" device on the inside of the fence enclosing the lot or corral. Find the best location for the wire by trial; a height of about 2 feet is suggested.

FEEDING AND CARING FOR THE COW HERD

Cows produce fewer pounds of meat per hundred pounds of live weight than any other class of farm animal. Because feed required for mainteance is roughly proportional to live weight, beef cows must be fed as much as possible on low-cost roughage and waste and byproduct feeds if they are to compete successfully with other classes of livestock.

In all beef-cow herd operations a middle level of nutrition is the most profitable. Feeding above this level will increase expense without commensurate increase in production. Keeping cows too fat may decrease fertility and milk flow. Undue limitations on feed quality and quantity will reduce productivity--particularly the percentage of calf crop--and thus reduce net income.

Pastures are the natural feed for beef cattle, and cows on good pasture ordinarily will not need supplemental feed. Some cattlemen think that beef cows on extremely succulent pasture early in the spring benefit if they are fed some hay or other dry roughage.

If you wean your calves in the fall, you may be able to maintain your beefcow herd until well into the winter on meadow or small grain aftermath, on stalk fields after corn has been harvested, or on permanent pasture where grass has been allowed to accumulate during the late summer. They can get most of their roughage from such material--feed that might otherwise be wasted. Usually this roughage is low quality, because it is mature and low in protein. If this is so, feed about 1 pound of protein concentrate per head daily.

Start winter feeding when pasture conditions demand it and before the cows lose much weight. Supply feed in small amounts at first and increase as necessary. Usually, feed the poorest hay or silage first and save the best roughage for late winter and the calving season. In many climates you can feed your herd on permanent pasture sod. This saves cleaning and manure hauling during the busy spring season.

Feed cows, yearlings, and calves separately. Separate cows into small groups for winter feeding so that the "bossy" cows can be separated from timid ones.

Rations for dry beef cows can vary widely, because they depend on the feed available. Include a source of vitamin A in the ration. You can meet a cow's daily requirements for vitamin A by feeding about 5 pounds of green-colored hay or 15 or more pounds of silage preserved so that its green color is well maintained.

A succulent feed is desirable but not essential in the ration of a dry beef cow. Silage is the most widely used feed of this type. Corn, sorghum, and various types of grass silage are exellent. Stock carrots or other root crops also are excellent, but they are not used much because of the labor needed to grow and harvest them.

To maintain weight, a beef cow needs about 2 pounds of dry matter daily per 100 pounds of live weight. Much of this can be straw, low-quality grass hay, corn stover, ground corncobs, cottonseed hulls, and similiar materials. Feed good-quality hay or silage in limited amounts or a cow will eat more than she needs and increase feed costs unduly.

Some examples of suitable rations for dry, pregnant cows weighing about 1000 pounds follow:

		Pounds
1.	Legume or mixed grass-legume hay	16 to 25
2.	Legume hay	5 to 10
	Straw or low-quality grass hay	10 to 15
3.	Corn or sorghum silage	30
	Legume hay	5
	Straw, low-quality grass hay, cottonseed hulls, ground corncobs, or other low-quality roughage	Unlimited
4.	Cereal straw	Unlimited
	Protein supplement	1
5.	Corn or sorghum silage	50 to 60
	Protein supplement	1
6.	Prairie or grass hay	Unlimited
	Protein supplement	0.5 to 1.0
7.	Grass silage	30 to 40
	Straw or low-quality grass hay	Unlimited

There has been some interest in wintering cows or heifers entirely on low-quality roughage such as ground corncobs or cottonseed hulls plus 2 to 3½ pounds daily of a highly fortified protein supplement like Purdue Supplement A.

Formula of 32-percent crude protein Purdue Supplement A:

	Pounds Per ton of mix
Soybean meal (44 percent)	1,286.2
Molasses feed (45 percent molasses)	571.6
Bonemeal	102.8
Salt	34.4
Vitamin A and D concentrate[1]	5.0

[1] Concentrated cod-liver oil with potency of 2,250 International Units of vitamin A and 300 International Units of vitamin D per gram.

A ration of 14.5 pounds of ground cobs, 3.5 pounds of supplement A, and 1 pound of ground alfalfa has proved satisfactory for wintering pregnant cows. Feed prices and availability determine whether you should use rations of this general type. Cost easily can be greater for rations of this type than for more conventional rations and no evidence indicates better results.

Unless your hay or silage is of very good quality, to stimulate milk flow you must feed concentrates to cows that drop fall calves and nurse them during the winter. Add 3 to 5 pounds of a 16-percent protein concentrate mixture to any of the rations listed. Silage is especially valuable for cows nursing calves.

When cows calve in early spring before pasture is available, feed them more liberally after their calves are large enough to benefit from an incrsased milk flow.

Except in the Deep South most of the perennial summer pasture grasses used for permanent pastures are dormant and have low nutritional value during the winter. If you use them for grazing during winter, feed a protein supplement. Usually it is more economical to feed harvested forage for a time each winter except in the most extreme southern areas.

In much of the South, well-fertilized temporary winter crops such as rye, oats, ryegrass, or mixtures of these with crimson clover will furnish grazing during the winter months. Productivity varies greatly, depending on the severity of the wintor and moisture conditions, and these crops furnish better grazing than is needed. Even cows nursing calves fatten excessively on such pastures. Grazing cows on such pastures for limited periods of 2 to 4 hours daily and feeding harvested roughage for the remainder of the daily ration can be economical and highly satisfactory.

If you live in the South, you can seed crimson clover in permanent sods to increase forage production in late winter and early spring and obtain excellent feed for cows and calves. The reseeding type of crimson clover eliminates the work involved in an annual seeding.

CARING FOR COW AT PARTURITION

The average gestation period of the cow is about 283 days, or about 9½ months. A variation of as much as 10 days either way from the average gestation length is not unusual.

As parturition approaches, the udder becomes distended with milk and there is a marked "loosening" or falling away in the region of the tailhead and pinbones. The vulva swells and enlarges considerably.

When cows calve during the grazing season, a clean pasture is the best place for calving. Chance of infection and injury is less than in a barn. Often, you can segregate cows expected to calve in a small pasture near the farmhouse where they can be frequently observed. If this is not possible, check the pasture at least twice daily during the calving season.

If you expect a cow to calve during severe weather, put her in a clean, well-ventilated box stall that has been disinfected or in a small pasture with underbrush or protected shelter. Cows in large herds normally calve without any change in ration. If you can provide individual care, reduce the daily ration as calving approaches and incorporate into the diet some mildly laxative feeds such as linseed meal or bran mash. This is helpful if the cows are on dry feed. Silage or other succulent feed is valuable at this time. However, cows getting only high-quality dry roughage usually get along well at calving time.

Most cows will calve normally without assistance. Be alert for signs of trouble and assist or call trained help if needed. If the cow has severe labor for more than 1 to 2 hours without result, assistance usually is needed.

If the calf does not immediately begin breathing when it is born, wipe out any mucus in its mouth or nostrils. Induce natural breathing either by forcing air into the lungs with a bellows or by alternate compression and relaxation of the walls of the chest.

In cold weather, protect the calf and keep it warm until it is dry and on its feet. Disinfect the navel of the newborn calf with iodine, as a precaution against navel ill.

After the cow has calved, give her all the water (preferably lukewarm) she desires. Return ration to normal in a few days. If the cow is an exceptional milk producer, she may have more milk than the calf can take the first few days. Milking out the surplus milk for a few days may make the cow more comfortable. However, many cattlemen in recent years have adopted the practice of milking only when the calf fails to nurse one or more teats. The milk output quickly adjusts to what the calf can take. Failing to remove excess milk does not increase the frequency of spoiled udders.

AGE AT WHICH TO BREED HEIFERS

If calves are to be dropped in a herd at only one season of the year, the owner must decide whether to breed heifers to calve first as 2-year-olds or 3-year-olds. At present no general recommendation can be made.

Several experiments have been carried out on this problem. It has been found that heifers bred to calve first as 2-year-olds will raise an average of approximately 0.7 more calves during their lives than heifers bred to calve first as 3-year-olds. Mature size is affected little if at all and length of productive life apparently is not reduced.

Disadvantages of calving first at 2 years of age are:

1. Heifers raise a smaller calf crop in their first calving season than if bred to calve first at 3.
2. A higher than average number of heifers calving at 2 often fail to rebreed to calve the next year.
3. A high number (about 50 percent in one survey) of heifers require help at calving.
4. Death losses may be higher than average.
5. Calf losses usually are higher than average.

The importance of these disadvantages has varied from experiment to experiment--in some cases, results have been so bad as to discourage the practice.

It would appear that breeding to calve first at 2 is profitable and is to be encouraged if (1) heifers can be grown rapidly and weigh 600 pounds or more at breeding, and (2) experienced help will be available at calving time and will have the necessary time to give special attention to the heifers. Breeding heifers to small, fine-boned bulls will minimize calving troubles but if this is done all the resulting calves should be marketed. This usually is not feasible in small farm herds where only one bull is used annually.

SEASONAL CALVING

In many farm beef herds, the bull is allowed to run with the cow herd the year around with the result that calves of all ages are on hand.

Although this system may result in more calves being raised over a period of years, if your herd is small it usually is preferable to limit breeding to a season of 2 to 4 months. If you limit breeding to a short period, you can choose the most favorable season for calving for your area. This system facilitates uniform and systematic management of the calves. If your herd is large, systematic calving at two seasons a year may be desirable and may increase calving percentages slightly since cows failing to settle in one season can be bred in the next. You can breed heifers to calve first at about 2½ years of age, which may be preferable to either 2 or 3 years.

Most beef calves are dropped in the spring. If weather is suitable, have calves born 6 weeks to 3 months before pasture season begins so that the calf is large enough to use the increased milk flow when the dam goes to pasture. Because it usually is necessary to wean calves at the end of the pasture season in the fall, having them born fairly early in the spring will result in older, heavier, and more valuable calves at weaning.

Fall calving requires more harvested feed for the cow herd. In the North, fall calves seldom do as well as calves born in the spring; fall calving, therefore, is justified only under special circumstances. In the South late fall or early winter calving often is desirable because of the relative freedom from screwworms at this season. Local circumstances and feed supplies should determine the time of the breeding season.

CREEP FEEDING CALVES

Creep feeding is feeding concentrates to nursing calves in enclosures that their dams cannot enter.

Giving 80- to 90-day-old nursing calves access to a concentrate mixture in a creep placed in the pasture where shade and water are available and where cows gather usually increases gains and the amount of finish carried at weaning.

Whether creep feeding will be profitable depends on the system of management and, to some extent, on the milk-producing ability of the dams. Calves from dams with good bred-in milk-producing ability get little benefit from creep feeding. Creep feeding often must be resorted to in drought years when feed supplies for cows are short and their milk production is reduced.

Since milk is high in protein, grain alone is a satisfactory creep feed. Feed grain, whole, cracked, or coarsely ground. Often, adding a small proportion of protein supplement (1 part of supplement to 6 to 9 parts of coarsely ground grain) will improve palatability. Calves eat an average of about 500 pounds of feed if they have free access to creeps after they are about 90 days old. The amount eaten varies greatly from herd to herd, however.

Creep feeding often will pay (1) in purebred herds where the finish that calves exhibit at weaning may have advertising value, (2) in commercial herds when the calves are to be marketed at or soon after weaning as fat baby beeves, and (3) during drought or other emergency.

Creep feeding ordinarily will not pay if calves are to be carried through a winter on limited rations prior to grazing for one or more seasons before marketing.

CALVES FROM DUAL-PURPOSE COWS

Calves from dual-purpose cows formerly made up a substantial proportion of the Nation's beef supply. Raising calves from dual-purpose cows is not likely to be profitable unless unpaid family labor is available. They usually are raised by one of two systems. With the double-nursing system, 2 calves of about the same age are suckled by 1 cow. The calves get along nearly as well as when they run with their own mothers in a strictly beef herd, although considerably more labor is involved. With this plan, half of the cows in the herd may be used for the production of milk.

With the other system, calves are taken from their dams on the fourth or fifth day after birth and bucket fed.

To teach a calf to drink milk, first permit the calf to suck your fingers and then immediately immerse your fingers in a bucket of milk. When the calf begins to take the milk in this way, withdraw your hand from the bucket. Buckets with rubber nipples often are used. This eliminates having to teach the calf to drink. After each feeding, clean and disinfect buckets and other utensils. Use a chlorine solution or a similar disinfectant.

Three or four pounds of whole milk are enough for a day or two after weaning. If the calf refuses to drink, do not force it; take the milk away. Twelve hours later, at the next feeding time, the calf probably will take milk. Increase the quantity by about a pound a day until the calf is getting 8 to 10 pounds a day.

After feeding whole milk for 10 days to 2 weeks, gradually replace it with skim milk. Make the change over a period of 5 to 7 days. Skim milk contains less energy and less vitamin A than whole milk. Feed a small quantity of cod-liver oil or other fish oil rich in vitamin A. If you have enough skim milk, increase the amount gradually each week until you are feeding 15 to 20 pounds per calf per day. If you want to conserve the milk supply, 12 to 14 pounds will be enough, provided you feed the calves enough suitable grain mixture, a protein supplement, and good hay.

Stop feeding cod-liver oil or other source of vitamin A after calves begin to eat hay, silage, or grass, provided the hay is green and leafy or the silage or grass has some green color. Be sure the calves have access to clean, fresh water and salt at all times. Calves readily learn to eat grain and should receive a limited amount each day from the time they are about 3 weeks old. Equal parts, by weight, of wheat bran, ground oats, and coarsely ground corn or barley is a suitable grain mixture.

As soon as possible, put the calves on pasture. If pasture is not available when calves are about a month old, cut and feed some growing crop or give them a small quantity of silage or carrots. Feed calves running on green pasture or confined in a lot or corral a little clean, bright hay from a rack.

WEANING CALVES

Wean calves that have been running with their dams on pasture by taking them away from the cows and confining them in a pen or barn out of sight of their dams and other cattle. Preferably, they should be far enough away from their dams to be out of hearing distance, but this is difficult on most small farms. Offer the calves some good hay and a small amount of grain during this period. Unless they were creep fed, they will eat little for a few days.

It formerly was recommended that calves being weaned be put back with their dams to nurse at increasingly less frequent intervals over a period of about 2 weeks. It was felt that this was necessary to prevent spoiled udders in cows and that it was less disturbing to the calf.

It now is known, however, that the safest and most effective method of drying off even high-producing dairy cows is to quit withdrawing the milk. The pressure built up stops further secretion. It is believed that both the dams and the calves will be better off if the calves are taken away and not put back with the cows.

Weaning bucket-fed calves is comparatively simple. Milk usually is withdrawn from the ration by the time they are 6 to 7 months old. If they have learned to eat hay and grain, the quantity of milk fed may be greatly reduced or eliminated several weeks earlier without stunting the calves.

DEHORNING AND CASTRATING

In commercial herds, and often in purebred herds, it is advisable to dehorn calves of horned breeds. This can be done most easily before the calves are 3 weeks old. At that age, the tender horn "buttons" first appear. Scrape them with a knife to irritate the surface. Prevent horn growth by carefully applying the slightly moist tip of a caustic pencil (stick of potassium hydroxide). The caustic causes a scab to form on the irritated area. After a few days, the scab shrivels and falls off, leaving a hornless or "polled" head.

Commercial liquid and paste preparations may be easier for many people to use than the caustic sticks. Young calves also can be dehorned by applying a heated iron to the base of the horn button. Electrically heated irons are convenient and satisfactory for use on many farms.

Male calves must be castrated to produce beef meeting American market requirements. Perform the operation preferably at a time of year when flies are not prevalent and before the calves are 3 to 4 months old. Some cattlemen castrate calves when taking birth weights.

Spaying of heifers seldom is practiced in farm herds. Contrary to the former belief, spayed heifers actually make slower gains and have no carcass superiority. Heifers should be spayed only on farms where they are being fattened and it is impossible to keep them separated from bulls.

SALT AND OTHER MINERAL REQUIREMENTS

At all times, supply stock with clean, fresh water and loose or block salt. On the average, cattle will consume about 2 pounds of salt a month--less for calves and more for steers on full feed and mature cows.

Requirements of cattle for other minerals vary from area to area and with the type of ration. Consult your county agricultural agent about probable needs in your area.

In some parts of the country, iodine is deficient. This deficiency leads to goiter or "big neck" in newborn calves. In these areas iodized salt should be fed. In other areas cobalt, copper, iron, and possibly other trace minerals are known to be deficient. These should be supplied.

Calcium often will be needed if beef cattle are not fed legumes or if the pasture is low in calcium. Phosphorus is deficient in the soil in many areas. Plants grown on these soils also are low in this element. Low-quality roughage, and mature, weather hay and grasses that are low in protein and carotene also are likely to be low in phosphorus.

Ground limestone usually is the cheapest calcium supplement. Phosphorus may be supplied in the form of steamed bonemeal, dicalcium phosphate, or defluorinated phosphates. Supplements should be fed as required in specific localities. Both calcium and phosphorus supplements usually are fed in mixtures with salt.

FEEDING CATTLE FOR MARKET

Many farmers with beef herds find it practicable to fatten the calves raised. The system used may be immediate full-feeding on heavy concentrate rations. An increasingly popular system of handling farm-raised steers, however, is to winter them at moderate nutritional levels the first winter, graze them a season, and then full feed them for 60 to 100 days just prior to marketing. This system permits marketing 18- to 20-month-old steers at approximately 1,000 pounds that grade in the high-good to low-choice range. Heifers can be handled under either system but ordinarily should be marketed at lighter weights than steers since they fatten more rapidly.

MILK GOATS

PRESENT STATUS OF THE INDUSTRY

Goats are especially useful to those who need a small quantity of milk and do not have the room or cannot afford to keep a cow. A goat can be kept where it is impossible to keep a cow, and the goat will consume considerable feed that otherwise would be wasted. The raising of goats is not limited to family use, however; many commercial dairies have been established successfully in areas where markets for the milk are favorable. The fact that goats are rarely affected with tuberculosis is another point in their favor. Milk goats are exceptionally clean animals and are more fastidious in eating habits than any other type of domestic animals.

GOAT'S MILK

Yield

About the first question that most people ask concerning milk goats is, "How much milk will one produce?" This is important, of course, as the value of a doe is estimated largely by her milk production. Even if a doe is purebred, she is of little value from the utility standpoint unless she is capable of giving a good quantity of milk. Many persons, in purchasing grade or even purebred goats, have been disappointed to find that the milk could be measured in pints and not quarts or gallons, as expected.

A doe that produces 1,000 pounds or about 500 quarts of milk (1 quart equals 2.15 pounds) during a lactation period of 10 months is considered a fair milker. A production of 1,200 pounds of milk is good, and 1,600 pounds and up is excellent provided it is produced in a lactation period of 10 months or less. Good does will produce 8 to 10 months in a year and from 8 to 15 times their weight in milk in a lactation period. Production records of some of the outstanding does in this country, together with records of some of the animals in the Department's herd, will be noted in the sections dealing with their particular breeds.

Characteristics

Goat's milk is nearly always pure white in color. The small size of the fat globules and the soft curd are two of its chief characteristics. The cream rises very slowly and never so thoroughly as in cow's milk. This condition makes impraticable the ordinary method of allowing cream to rise. It has been stated that goat's milk will not keep sweet so long as cow's milk, but tests have shown that this is not the case. The keeping quality of any milk depends on the conditions under which it is produced and handled.

In tests made by the Department of Agriculture it was found that goat's milk could be thoroughly separated in a separator. After milk testing 4.4 percent of fat was run through the separator, the milk then tested only 0.03 percent of fat.

Composition and Nutritive Properties

Goat's milk is a healthful and nutritious food. The milk of Saanen and Toggenburg goats resembles that of Holstein cows in percentage of water, lactose, fat, protein, and ash, although subject to greater variation with the advance of lactation than milk of either Holstein or Jersey cows (table 1). The percentage of total solids in goat's milk ranged from 13.05 in February to 10.78 in August.

The small fat globules and the soft curd of goat's milk contribute to its ease of digestibility. Some persons who are allergic to cow's milk can consume goat's milk readily, due largely perhaps to its easier digestibility. In a great many cases goat's milk has proved especially valuable for infants and invalids.

The U.S. Department of Agriculture in cooperation with Johns Hopkins University conducted a series of studies on the nutritional properties of goat's milk as compared with those of the milk of Holstein-Friesian and of Jersey cows. Under the supervision of the University, normal infants were fed milk from the three sources. The milk was boiled for 1 minute and supplemented with orange juice and cod liver oil. No essential differences in health, general appearance, and well-being of the infants were observed, good results being obtained with each milk. The gains in weight were in proportion to the total nutritive content of the milk. In these studies, no attempt was made to use babies with a history of malnutrition.

TABLE 1.--Comparison of the composition of goat's milk and that of two common breeds of dairy cows.

Source of milk	Water	Total solids	Fat	Protein	Lactose	Ash
	Percent	Percent	Percent	Percent	Percent	Percent
Goats	88.02	11.98	3.50	3.13	4.55	0.80
Holstein-Friesian	87.50	12.50	3.55	3.42	4.06	.68
Jersey	85.31	14.69	5.18	3.86	4.94	.70

In one of a series of nutrition studies in Pennsylvania and Texas, a preliminary investigation was made of the value of goat's milk in the diet of growing children. This work has been summarized as follows:

"In an institutional nutritional investigation, 38 children ate the same basic dietary, with the children divided into two equal groups, each consisting of 19 children (10 girls and 9 boys). One of the groups drank 1 quart of goat's milk and the other 1 quart of cow's milk daily, in the 5-month study.

"Numerous medical-nutrition observations and tests were made on the children before the study began and at its close.

"(1) The children who drank goat's milk surpassed those who drank cow's milk to an extent which was statistically significant in the following respects: (a) Weight for the sex, age, body size, and body build; (b) skeletal mineralization, or bone density; (c) blood plasma vitamin A; (d) blood serum calcium; (e) urinary excretion of thiamine, or vitamin B_1; (f) urinary excretion of riboflavin, or vitamin B_2; and (g) urinary excretion of F_2, a fluorescent substance related to niacin.

"(2) The group of children who drank cow's milk exceeded the goat's-milk group by an extent which was statistically significant in growth, although both groups made excellent growth progress.

"(3) The goat's-milk group tended to exceed the other group in the following respects, although the differences between the two groups were not statistically significant: (a) Skin dryness as observed biomicroscopically; (b) hemoglobin concentration in the blood; (c) total protein in the blood serum; (d) reflex action; (e) overall score by the medical examiner.

"(4) The two groups showed no difference in their progress from the initial to the final test in the following: (a) Skeletal maturity; (b) condition of the conjunctiva, or normally transparent covering of the eyeball; (c) corneal vascularization; (d) condition of the tongue; (e) condition of the gums; (f) condition of the skin except for unusual dryness (see above); (g) red cell count; (h) packed cell volume; (i) leucocyte or white cell count; (j) differential cell count; (k) blood plasma carotene; (l) blood plasma vitamin C; (m) protein fractions in the blood; (n) blood serum phosphorus; (o) functioning of the heart; and (p) resistance to fatigue.

"This 5-month study must be regarded as preliminary. Whereas the results of this study are strongly indicative of the fact that goat's milk has some superior qualities, the work should be extended before final conclusions are drawn."

GOAT'S-MILK PRODUCTS

Goat's milk can be utilized for the same purposes as cow's milk, although for some it is not nearly so well suited. For general use, such as drinking or cooking, the milk has proved to be very satisfactory. Where a market exists for fluid milk this is by far the most profitable. Goat's milk is less satisfactory than cow's milk for making butter, but large quantities of goat's-milk cheese are manufactured, especially in Europe.

The milk of some of the largest herds in the country is evaporated and sold in that form. Goat's milk frequently may be purchased at drug or health-food stores in evaporated, dehydrated, or powder form.

Butter

Good butter can be made from goat's milk, but ordinarily very little is produced. The cream rises very slowly, and only a portion of it reaches the top. By the use of the separator, however, practically all the butterfat can be obtained. Unless artificially colored the butter is very white and resembles lard in appearance. If colored, it resembles cow's butter, although it does not have the same texture. It can be used for the table or for cooking. A good quality of butter with no objectionable features is produced when the milk and cream are properly handled. However, when a good price is obtained for the milk, it does not pay to make butter, as cow's butter is cheaper.

Cheese

Several varieties of cheese, known under various names, are made from goat's milk. In France, goat's-milk cheese is called Chevret, or Chevrotin; in Italy, Formaggio di Capra; and in Germany, Weichkäse aus Ziegenmilch (soft cheese from goat's milk). Goat's-milk cheese has a characteristic and individual flavor all its own, depending on the process and cultures used. The products closely resemble cow's milk cheeses made by the same processes. The cheese may be made either entirely of goat's milk or, better with from one-fourth to one-third cow's milk; the mixture materially improves the quality of the product.

Hard cheese may be made by the following method: "A junket tablet is dissolved in ½ cupful of cold water and stirred into a gallon of milk which has been heated to 88°F. After 30 minutes the curd is cut into cubes about 1 inch in diameter. For this purpose a large knife is used and after cutting in two directions vertically a horizontal cutting is made to complete the cubes. Sometimes it is convenient to make the horizontal cuttings with a bent wire.

"The container with the curd is placed in a pan of water at 100° F. This temperature is maintained so that the temperature of the curd will be 98°F. after 1 hour. The curd is stirred frequently while being heated. In from 30 minutes to 1 hour after heating, the curd is poured with the whey into a muslin bag. After 2 or 3 hours the curd can be removed and placed in a mold formed by rolling the cheese in a small square piece of muslin. This cheese ball is then placed in the container (a cylinder), using an inverted plate as a false bottom. Another plate is placed on top of the cheese. This is weighed down.

"After 24 hours the cheese is removed from the muslin cloth and rubbed in salt. It is rubbed in salt again the following day. These cheeses can then be stored in a cool place and rubbed daily for a week to prevent mold growth and to get a good rind formation. This cheese is ready for eating when 10 days old. If the cheese cracks while it is curing, its surface can be rubbed with a neutral oil or butter."

Cottage cheese may also be made from goat's milk. By one method "Skim milk is held at a temperature of about 75°F. until it develops a firm curd. When this curd is sufficiently firm, it is cut into pieces about 2 inches square with a long knife or large spoon. Then the vessel containing the broken curd is placed on the edge of the stove or in a vessel of water, and heated very slowly to 100°F. The mass is kept at that temperature for about 45 minutes to firm the curd.

During the heating and holding period the curd is stirred gently with a spoon or ladle to prevent it from lumping and to secure uniform heating. When it is sufficiently firm so that the pieces yield no milky whey and do not bind together when gently squeezed in the hand, the curd is poured into a porous sack or a colander to drain. The flavor and the keeping quality of the cheese will be improved if the curd is washed in cold water when the draining is practically complete. After this wash has been thoroughly drained from the curd, about 1 teaspoonful of salt is added for each pound of cheese, is mixed in well, and the product is stored in a cool place."

GOAT DAIRIES

Numerous goat dairies are in operation in different parts of the country. These dairies have been established both for the production of milk and the manufacture of milk products. One of the largest goat dairies in the country is devoted to the manufacture of condensed milk. If only a few goats are kept it is not necessary to have much equipment, but if a considerable number of does are milked it is best to have the proper equipment for handling the work advantageously. This does not mean, however, that expensive buildings must be provided. Any clean, dry quarters free from drafts may be used. The building should have proper ventilation and an abundance of light, and be so arranged that each goat can be fed and handled properly.

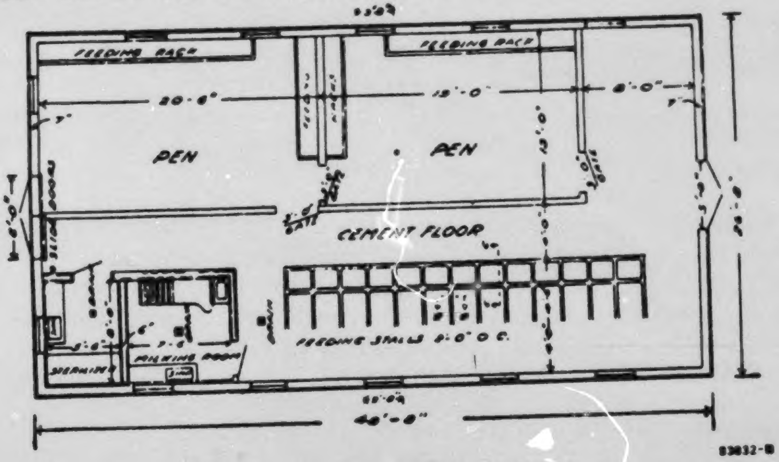

Figure 1.—Plan of a practical goat dairy.

Figures 1 and 2 illustrate a practical goat dairy and show the requirements necessary to handle a medium-sized herd satisfactorily. There are pens in which the does may be handled together, and stalls in which they can be fed individually. If the goats are provided with leather collars or neck chains, they can be tied to the mangers in the stalls by means of a short rope or chain with a snap on the end which fastens to the ring on the collar.

At kidding time small temporary pens can easily be made by the use of hurdles. After the does have kidded they should be transferred to the stalls. Until the kids are at least a month old they should be fed and handled in the temporary pens.

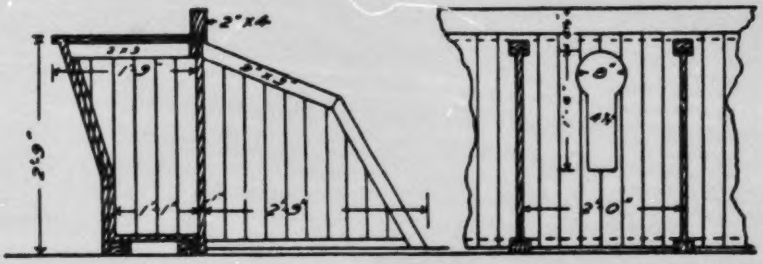

Figure 2.—Left, side view of single stall and manger; right, division between stall and manger. The opening allows the goat to feed and prevents the waste of feed.

In the plan (fig. 1) the milking room is separated from the main room and has a concrete floor. The walls and ceiling are plastered so that they can be washed with a hose. This room is equipped with a sink, milk scales, and milking stand. The milk is handled in another room, equipped with a cooler, a sink and a sterilizer. The grain is kept in feed bins at the opposite end of the dairy. Space for the storage of hay can be provided either in some nearby building or in a mow above the main dairy barn.

BREEDING AND SELECTION

The development of superior individuals or lines of breeding in milk goats as with other animals is dependent upon the interactions of heredity and environment. Good breeding will develop outstanding individuals only if the right kind of feeding and management practices are followed. Similarly, the best feed and management possible will not produce a desirable type of goat with high milk and butterfat yields unless the individuals carry the breeding for these characteristics.

Improvement in goats is brought about chiefly through hereditary factors transmitted through the germ cells. Effort, therefore, should be concentrated toward improvement by so mating the animals as to recombine these factors in more desirable forms. The various recombinations which may take place are the hope and despair of animal breeders. Without such variations, there is no opportunity for improvement; with them there is no assurance of fixing a type without constantly selecting animals with desirable characters and discarding those with undesirable ones.

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Through selection, the goat breeder has the means of controlling the inheritance of his animals. He can decide which of his animals shall have many offspring, which shall have few, and which shall have none. As a guide in estimating whether an animal has the hereditary factors that will enable it to approach the desired ideal, certain procedures are of value and should be used in practical breeding. Individuality, ancestry, and performance must all be taken into account. Each has its value or its limitations, and no single formula for the amount of attention to give to each can be generally prescribed.

Selection of the Buck

The buck is usually considered half the herd and, in order to make progress in breeding, care should be exercised in making this selection. As good bucks are scarce, it is not always possible to get the type desired, but the best obtainable should be procured even if the cost is a little greater. Select a buck from a good-producing doe that is a persistent milker. There is nothing more important in the matter of breeding than evidence that the entire family to which the sire belongs is especially good in performance and in conformation. The success of breeding any class of animals depends largely on the selection of the sires. The selection of a single sire has made many herds famous.

A buck should be masculine in appearance, of at least medium size for his age, and of good conformation. As regards the latter, a good depth of body is one of the most important considerations. The masculinity of the buck can be determined by the size and conformation of the head, amount of bone, and the quality and length of the hair on various portions of the body. The legs should be straight and well placed. Always select a vigorous buck. Thinness is no objection if the buck is healthy and a good feeder. A good buck is seldom in good flesh, especially during the breeding season.

Most breeders at the present time prefer bucks that are naturally hornless. The kids of such bucks are usually without horns. The type of doe to which the buck is bred will, of course, have some influence in this respect.

When only a few does are kept, it is cheaper and more convenient to send them away to be bred. A buck is usually a troublesome individual, and must be kept away from the rest of the herd. The charges made for outside breeding are usually reasonable.

Many small breeders are compelled to use crossbred or grade bucks; in such cases selection should be made upon conformation and breeding. Always use purebred bucks when available.

Selection of the Doe

Although it is not always possible, it is much more satisfactory in making selections to see does during their lactation period. This not only gives an opportunity to study their conformation when they are producing, but the udder development, which is so important, can be better observed.

A good doe should have a feminine head, thin neck, sharp withers, well-defined spine and hips, thin thighs, and rather fine bone. The skin should be fine and thin over the ribs. She should have good digestive capacity, as shown by the spring of rib and size of stomach. The so-called wedge shape of the dairy cow is clearly defined in a good milk doe. The constitution, an important item, is indicated by the depth and width of the chest. The udder should be of good size when filled with milk and very much reduced when empty. A large udder does not always indicate a high milk yield unless it is of the so-called "genuine" type. The teats should be large enough to make milking easy.

In selecting a doe, the first questions that are naturally asked are: How much milk will she produce and how long will she milk? While some does milk for only a few months after kidding, others continue producing for 8 to 10 months or even longer.

In selecting does, especially when they are giving milk, avoid those that are fleshy; this is a strong indication that they are not good producers. Select those of the dairy conformation.

Owing to the scarcity of good purebred does and the prices asked for them, it is much more economical to begin a herd by selecting good grade does, such as are found in many sections of the country, and breeding them to superior bucks of the leading breeds. By keeping the best young stock and breeding them back to good bucks selected for high producing offspring, a grade herd can be developed that will outproduce purebreds of the quality most breeders are willing to sell. Another way is to buy the best purebred doe kids that the buyer can afford from reliable breeders.

Methods of Breeding

Since the ultimate success of the goat breeder in the improvement of his animals depends not only on his skill in their selection but upon the judicious mating of them as well, it is essential that he have at least a general understanding of the systems of breeding used in the improvement of goats and other livestock.

Inbreeding is the mating of animals which have a closer relationship to each other than the average relationship within the species or breed concerned. Only animals of excellent merit and few defects should be used in such a system. Mating of sire to daughter, son to dam, full brother and sister are examples of this system. Animals resulting from such matings are more likely to transmit their good characteristics than animals which are possibly as good individually but which have resulted from outcrossing or random breeding. However, this type of breeding also tends to bring out recessive characteristics not apparent in the parents which may be undesirable and the breeder should be quick to cull rigidly in order to keep only the good qualities.

Linebreeding is mating animals so that their descendants will be kept closely related to some animal regarded as unusually desirable. It is accomplished by mating animals that are both closely related to the unusually desirable ancestor but little if at all related to each other through any other ancestor. Since both parents are related to the animal toward which the linebreeding is being directed, they are related to each other.

This system is used extensively and is recommended when the ancestor to which all offspring trace is of special merit and free from serious defects. However, the chances of getting inferior offspring are too great to employ it on average stock in order to avoid the purchase of a new buck.

Crossbreeding is the mating of two animals which are both purebred but belong to different breeds. The hybrid vigor often results in superior individuals. These are not usually satisfactory as breeding stock due to their complex genetic inheritance. However, on account of the general dominance of genes favorable to size, vigor, fertility, and production, goat raisers interested primarily in milk production employ this system with good results.

Outcrossing is the mating of animals of the same breed but which show no relationship for at least the first 3 or 4 generations. It is a relatively safe system to use, for it is unlikely that two unrelated animals in a breed, selected more or less at random, will be carrying the same undesirable genes and pass them along to the offspring.

Grading up is the practice of using purebred sires of a given pure breed on native or grade females. Its purpose is to develop uniformity and to increase productivity and quality in the progeny. This system of breeding is the most economical way of rapidly lifting the milk production of commercial stock.

Age of Breeding

Goats are in their prime when from 4 to 6 years of age, but choice individuals and good breeders may often be kept to advantage several years longer. The general practice is to breed young does when they are 15 to 18 months of age, at which time they will be practically grown if they have been well cared for. Most breeders have their does kid in the months of February, March, and April, and breed them but once a year. However, some people who keep only a few goats desire a milk supply during the entire year and breed a part of the does to freshen during the fall or early winter. Well-grown young does can be bred to advantage when from 12 to 15 months of age.

Does will sometimes breed at an early age and care should be taken not to allow them to become pregnant too young. Cases are recorded in which does have kidded when less than 9 months of age.

Periods of Heat

Does come in heat regularly between September and January, and somewhat irregularly and with less intensity from January to March. After this only an occasional doe can be bred until late in August, when the entire herd will come in heat again. When they come in heat and desire the attention of the buck they make their condition known by uneasiness and constant shaking of the tail. They usually remain in heat from 1 to 2 days. The period between heats is ordinarily about 21 days. From the record kept of the Department's herd, most does have returned in from 17 to 21 days, but sometimes they will return in from 5 to 7 days after service. This, however, may be an indication that something is wrong with the doe. Bucks are continually of use for service from the fall to the spring season. It is during this time that they have such a strong odor. The number of does to breed to one buck depends on his age and condition. An early spring buck kid, if well grown and properly handled, can be bred to a few does the following fall. A buck from 12 to 18 months of age can be bred to at least 25 does, and a mature buck is sufficient for from 40 to 50 does.

Out-of-season Breeding

Breeders experience much difficulty in getting does to breed during the late spring and summer months. This seasonal restriction in the breeding of does creates a problem of maintaining a fairly uniform level of milk production throughout the year and is of much concern to goat dairymen and others who would prefer a fairly constant supply of milk. Several possible means of spreading the period over which does come in milk have been investigated by research workers and in some instances applied by breeders. Probably the most practical ones are: (1) Delayed breeding of a part of the does in a herd so that some are bred at different times during the breeding season, (2) pen breeding virgin or dry does during the spring and summer months, by permitting a buck to run with them, and (3) selection of does that tend to come in estrus outside the usual breeding season, thereby increasing the spread in possible breeding dates.

Until other methods can be developed, the first and second ones can be considered the most practical. Even these are not so easy of application in small herds as in large ones where there is more opportunity for separation of animals into groups for early and late breeding. Reserving some does for late breeding may also result in a few dry does since goats do not breed with as much certainty during the latter part as in the early months of the breeding season.

To develop a strain of goats which would consistently breed out of season, if possible, would require many generations of vigorous selection for the trait.

The injection of hormones to produce out-of-season breeding has not proved effective in the Department's herd and in some cases has proved detrimental in retarding the occurrence of natural estrus and thereby delaying the effective breeding. Therefore, this practice cannot be recommended to the practical breeder.

Gestation Period

The gestation period, which is the time between the effective service of the buck and the birth of the kid or kids, ranges from 146 to 152 days. It is usually spoken of as 5 months. The average gestation period recorded for several years in the Beltsville herd of Toggenburg does was 146 days.

Number of Kids

Milk goats are very prolific. The usual number of kids at one time for mature does is 2, but frequently there are 3, and it is not a rare thing, especially among the common American goats, to have a doe produce 4. Yearling Toggenburg does at Beltsville have produced kids at a rate of 168 per 100 does, while the mature Toggenburg does have produced kids at the rate of 196 per 100 does. Records indicate little difference between Toggenburg and Saanen breeds in this respect.

FEED AND MANAGEMENT

Successful goat production, as with other livestock, requires the use of proper feeding methods. The ability to convert feed into milk is inherited. Consequently, one of the most important problems of the goat breeder is to so feed his goats that this inherited ability is utilized to the maximum. Unless feeding permits full development, intelligent selection cannot be made of the animals which can transmit the desired characteristics. Undernourished does that never had an opportunity to demonstrate their capacity to produce milk, and bucks lacking in growth and vigor, are difficult to appraise accurately.

The Buck

In handling goats, the bucks are a considerable problem. Their strong odor and disgusting habits cause many people to take a great dislike to goats. Bucks should be kept away from the does except when desired for service. If they are kept in the same barn or room where the does are milked, some of the strong odor is likely to be absorbed by the milk. Place the bucks in a separate barn or shed, with a lot sufficient for exercise and pasture.

The best results can be expected only when the bucks are kept in a healthy condition. During the winter months the ration should consist of a hay--alfalfa, clover, or mixed hay--and corn stover, with some succulent feed such as silage and turnips, and a sufficient quantity of grain.

The bucks in the Department's herd are usually wintered on 3 pounds of alfalfa or clover hay, 1 to 1½ pounds of silage, and 1½ pounds of grain a day, the grain mixture consisting of 100 pounds of corn, 100 pounds of oats, 50 pounds of bran, and 25 pounds of linseed meal. During the breeding season the grain ration for mature bucks is usually increased to 2 pounds per head daily. When the bucks are on good pasture, no grain is necessary.

During the breeding season it is usually necessary to keep the bucks separate, or they will fight and are likely to injure one another. A wood lot with plenty of browse is an excellent place for them during the summer. Goats are browsers by nature and prefer leaves, twigs, and weeds to grass.

It is often necessary to protect the trees in the lots and pastures by putting around them a framework covered with close-woven wire. This is true especially of the young trees. If no lot, or only a small lot, is available for feed and exercise, the buck may be tethered out. Vacant lots can often be utilized to advantage. Fresh feed as well as a variety is thus afforded.

The Doe

Most of the feeds that are valuable for the production of milk for dairy cows are also suitable for does. From 6 to 8 goats can be kept upon the feed required for 1 cow. When does are in milk, they should be allowed all the roughage that they will consume, such as alfalfa, clover, or mixed hay and corn stover. They should receive a liberal quantity of succulent feed, such as silage, mangel-wurzels, carrots, rutabagas, parsnips, or turnips. The grain feeds best suited for their ration are corn, oats, bran, barley, and linseed meal or linseed cake. Other feeds that are often available and that can be utilized are cottonseed meal, brewers' grains, corn bran, gluten feed, and beet pulp.

A ration that has proved to be very satisfactory for does in milk during the winter season consists of 2 pounds of alfalfa or clover hay, 1½ pounds of corn silage or roots, and from 1 to 2 pounds of grain. The grain ration consists of a mixture of 100 pounds of corn, 100 pounds of oats, 50 pounds of bran, and 25 pounds of linseed meal. When the does are on pasture they receive from 1 to 1½ pounds per head daily of the grain mixture.

There is a great difference in individual goats; one goat may readily eat a ration that another may not like so well. As in the case of dairy cows, each doe should be studied if the best results are to

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be obtained. It is best to feed separately each doe that is giving milk. This not only affords an opportunity to study each individual but also insures that each one receives the quantity intended for her. A good practice is to feed grain on the basis of a doe's milk production; that is, at a ratio of 1 pound of grain for each 3 or 4 pounds of milk produced, with a daily minimum allowance for all does of 1½ pounds of grain per head.

In the Department's herd of Toggenburg does an average of 1.0 pound of grain is required to produce a quart of milk, on the basis of the daily consumption of grain throughout the entire period of lactation. Approximately 500 pounds of hay and 450 pounds of grain a year are required for a mature doe, provided of course, that good pasture is afforded as much as 6 months of the year. If no pasture is available about twice the amount of hay and 20 percent more grain is required. It is estimated that 1 acre of good pasture is sufficient for 2 to 3 mature goats during a grazing season 5 to 6 months in length. If grain and hay are to be grown for the goats, additional acreage must be provided for this purpose. Goats relish browse, but a doe cannot be expected to produce milk at her maximum level without the addition of good legume hay or other pasture plus a grain ration.

Young does should be kept growing. In the spring, summer, and fall, if they have plenty of browse and pasture, no grain is necessary. If no browse is afforded and the pasture is short during certain months, give them a little grain. In winter they should be fed about 1 pound of grain, 1 to 1½ pounds of silage or roots, and all the hay or fodder they will consume. They should have a shed for shelter and protection from the wind. Goats must be kept dry and out of cold winds for best results.

Some goat breeders make it a practice to gather leaves in the fall and store them for winter use. This practice should be resorted to only in cases of shortage of more desirable feed. Leaves may be used for bedding, but even for this purpose they are only fairly satisfactory. If only 1 or 2 goats are kept, refuse from the kitchen, such as potato and turnip peelings, cabbage leaves, and waste bread may be utilized for feeding. If necessary, does may be tethered out, as described in connection with handling the buck.

All feed offered to goats should be clean. Rations should be made up from the best feeds available and those most relished by the goats. Salt should be provided in the form of medium fine stock salt with trace minerals. Phenothiazine can be mixed with this in the proportion of 12 to 17 parts salt to 1 part phenothiazine without coloring the milk. This provides some protection from internal parasites as the does consume their salt requirement. In order to be sure they get enough phenothiazine to protect them, no other salt should be provided and mixed feed containing salt should not be used. A good supply of fresh water is necessary; goats should not be compelled to drink from pools where the water has been standing.

Lactation period

The lactation period, which is the time that a doe produces milk, varies considerably in the different breeds and types of goats. It ranges all the way from 3 to 10 months, or even longer. A lactation period ranging from 8 to 10 months is considered very satisfactory. There are certain conditions, such as the breed, individuality, health, feed, and regularity and thoroughness of milking, which may influence it. Purebred does of any of the leading breeds, as a general rule, will milk longer than any of the so-called common, or American type. The breed that has been developed the longest should, of course, excel in this respect if the animals have been properly selected. There are always individuals in a breed that excel along certain lines, and this is especially true as regards length of lactation period.

The health of the does while giving milk is of special importance. When does are out of condition frequently their milk yield shricks, and in many cases, they have to be dried up. Proper feed and regular feeding have a tendency to extend the lactation period not only by stimulating the production but by causing a more uniform flow during this time. The milking must be done regularly and thoroughly if good results are desired. Irregularity and neglecting to draw all the milk from the udder have a tendency to shorten the period.

Milking

As young does usually object at first to being milked, the stanchion arrangement shown in the illustration is an excellent method of handling them. For the first few times at least it is best to give the does a little grain feed in the box attached to the stanchion. Does soon become accustomed to being milked and after a few times will jump up on the stand and put their heads through the stanchion without being assisted.

The doe's udder should always be either washed or wiped thoroughly before being milked. Ordinarily a damp cloth is sufficient to remove all foreign material. The first milk drawn should not be saved, as the openings in the teats may be partially filled with foreign matter which will be removed after a little milk has been drawn. It is best to have a room for milking separate from the main goat barn. This prevents the milk from absorbing any odors in the stable.

There are two systems of milking goats: From the side, as cows are milked, and from the rear. This latter method is largely a European style and is used very little in the United States as there is more opportunity for contamination of the milk from dirt and droppings. Commercial dairies usually make milking arrangements to conform to local health regulations.

There are also two systems of drawing milk from the udder: One consists in pressing the teat in the hand, as is usually practiced in milking cows, and the other is "stripping." The first can be adopted when the teats are of sufficient size to be grasped by the hand. The other method is necessary only for goats with small teats or for goats in their first lactation, before the teats are fully developed. In stripping, the teat is grasped between the first finger and the thumb close to the udder and drawn down the entire length, sufficient pressure being exerted to cause the milk to flow freely.

A heavy producer may have to be milked three times a day for a short time, but twice is sufficient for most does. The period between milkings should be divided up as equally as possible. Milk should not be used for human consumption until the fourth or fifth day after the doe gives birth to kids. Some authorities recommend waiting longer, but this is not necessary if everything is normal. Regularity in milking is important, and kindness and gentleness should be regarded as essential. It is advisable that the milking be done by the same person so far as possible. Milking machines especially designed for goats are used in many commercial dairies.

Care of the Milk

Utensils used in handling the milk may be purchased from goat dairy supply houses. All utensils should be kept clean. A sanitary stainless steel milking pail with detachable hood has been satisfactory at Beltsville. These pails are of 4-quart capacity. As soon as the milk is drawn it should be weighed, strained, and cooled. The weighing is necessary if one is to determine accurately how much a doe produces. Milk records are especially valuable to the breeder in selling stock as well as in selecting breeding animals.

The milk should always be thoroughly strained to remove any foreign matter. The best method is to use commercial filters or strainers, but it is possible to use a layer of sterilized absorbent cotton between two cloths, or to pass the milk through several thicknesses of cloth. Cheesecloth is best for this purpose.

To check the growth of bacteria the milk should be cooled to a temperature of 40° F. as soon after milking as possible. This may be done by placing the cans in a tank containing cold water. One of the best systems of cooling the milk rapidly, however, is to run it over a cooler inside of which is cold, running water. Milk should be kept cool until wanted for use. Complete information on the production of clean milk is contained in Farmers' Bulletin 2017.

Sometimes undesirable flavors appear in the milk. These may be due to strong feeds such as wild garlic or strong-flavored weeds or vegetables consumed by does too near to milking time. Good flavored milk results from proper handling, such as keeping bucks separate from the milking does, using perfectly clean utensils, cooling the milk rapidly after it is drawn, and keeping it refrigerated. Occasionally, owing to ill health or some systemic disorder, individual does will give poorly flavored milk. Theories have been advanced that individual does vary in the amount of fatty acids secreted in the milk, and thus does receiving the same feed sometimes produce differently flavored milks. Some breeders believe that off-flavored milk is an inherited characteristic. Still others have observed that does milked for unusually long lactation periods tend to produce milk of poor flavor. Experimental study of this problem is needed.

Because pasteurization of goat's milk distributed for human consumption is required by public-health authorities in many localities, its effects on nutritive values are important. Studies by the Department have shown that the solubility of calcium and phosphorus is slightly increased and the curd tension is reduced by pasteurization. This process improves the keeping quality more than the flavor of fresh goat's milk. Pasteurization by holding the milk at not less than 142° F. for 30 minutes caused a decrease of from 33 to 45 percent in the content of reduced ascorbic acid, or vitamin C.

Care of the Doe during kidding

Ordinarily the doe and kid need no special care during and after kidding. A few days before expected parturition the doe should be given a small stall where she may be alone. Plenty of clean bedding, such as straw, leaves, or shavings should be provided. She may have all she will eat. If she is indifferent about food, adding carrots, beets, or small pieces of apples to her ration may induce her to eat.

Assistance at birth is seldom required. Small or young does kidding for the first time may need help. Parturition may require an hour. If it is not completed by the end of 2 hours, assistance should be given. Wash the hands and arms with soap and warm water and a mild disinfectant, such as a 10-percent solution of therapogen. This is made by taking one part of therapogen and diluting with 9 parts of water.

Examine with the hand the position of the kid in the uterus. Normally the two front feet should be felt first with the nose resting on the front legs. Fasten a stout cord which has been disinfected in the solution to the kid's front legs and pull gently as the doe strains. The kid's head should move along with the legs. Once the forelegs and head are passed there will usually be no further trouble. If one leg is doubled back, it should be straightened out so that it lies alongside of the other so that both will come out together. Never pull on the front legs unless the head is coming along with them.

If the kid is in a posterior position, the two hind feet must be expelled together. Attach a cord to them and proceed as in a forward presentation.

In a backward presentation the kid's back is sometimes downward. In this case the kid should be turned in the passage so that its belly will be downward before any pulling is done.

After the kid is out, dry it off with a clean dry cloth and put it near the doe. She will usually lick it clean and otherwise care for it. A second or third kid may be born following removal of the first one. The afterbirth as soon as passed should be burned or buried. If the afterbirth is retained for more than 24 hours, or if there is inflammation of the uterus, 2 to 3 ounces of mineral oil containing one-half dram of iodoform may be introduced into the uterus through a sterile soft rubber tube. This loosens the attachment of the after birth to the womb and prevents bacterial infection.

After the kid gets up and starts to nurse, make certain that it is getting milk. Stripping the teats a few times will indicate the presence or absence of milk. If the teat is not open a veterinarian should be called. The kid or kids should receive the first milk, or colostrum. If hand feeding is to be used the kid should not be allowed to nurse the doe at all, but should be fed from a bottle with a nipple for the first few days, then taught to drink from a pan. If the kid nurses the doe, see that both halves of the udder are emptied uniformly. The udder should not be allowed to become hard.

Raising the Kids

The raising of the kids is especially important when it is desired either to sell or use the milk for family purposes. If the kids are not to be raised, they can frequently be sold for pets or for meat when 2 to 3 months old. Kids that are allowed to suckle their dams not only make good growth but require very little attention as compared with those raised by hand. However, hand-raising helps avoid ill-shaped udders which sometimes result from uneven suckling, prevents weaning difficulties, and provides a check on milk production.

The quantity of milk to be fed and the length of time that it should be fed depends on several conditions. Kids dropped in the spring do not require so much milk or need to be fed so long as those dropped in the fall or early winter. The quantity of milk required for a kid can be determined readily from the fact that a doe producing from 3 to 4 pounds of milk a day can easily raise two kids satisfactorily. This means that each kid needs 1½ to 2 pounds of milk a day, or 1¼ to 2 pints. The Department in an experiment allowed several does with records of a little above 4 pounds of milk a day to suckle 3 kids, feeding the kids also some hay and grain. The kids made a fairly good growth, which shows that the amount of milk can be decreased if other feed is supplied.

Studies in the feeding of kids by hand in the Department's herd have shown that after they have reached 10 weeks of age the milk may be replaced in a large measure by good alfalfa hay and mixed grain without sacrificing body weight and development. During the period of 10 to 18 weeks of age, the kids in one lot were given 60 pounds less of milk than the check lot, and all were fed all the hay and grain they would clean up. The kids on the restricted milk diet consumed on the average 9 pounds more of grain and 2 pounds more of hay

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during this 8-week period than the kids in check lot. The average weight of the kids in the 2 lots was identical at the close of the feeding test. This substitution of grain and hay for milk in kid feeding is economical, as it takes approximately 1 pound of grain to produce 2.2 pounds of milk.

Kids to be raised by hand should not be allowed to nurse the doe. They should, however, be given the colostrum or first milk which is so valuable to them during the 2 days following birth. This milk should be fed at frequent intervals from a bottle and nipple.

Kids can be raised satisfactorily on whole cow's milk, and some goat breeders have adopted a system whereby skim milk has been used with a fair degree of success. The kids should be changed from whole to skim milk very gradually, the quantity of skim milk being gradually increased until it makes up the entire milk ration. After this has been done the kids will usually consume from 2 to 3 pounds a day. They should be given just as much as they will drink readily, and until they are at least 6 weeks old they should be fed three times a day. During this time the milk should be warmed and fed at a temperature ranging from 90° F. to not more than 98° F. The kids can be weaned from milk when they are from 3 to 4 months old. At about 8 weeks of age the digestive system of kids is usually sufficiently developed so that they can obtain substantial nourishment from solid feeds. At weaning age they will consume sufficient hay, grain, and pasture to make a good growth. Some of the leading goat breeders do not wean the kids until they are about 5 months of age. The age of weaning, however, should depend upon the system of raising the kids. If raised by nursing the does, they can be allowed to remain in the herd until 5 months of age; but if they are raised by hand feeding and the supply of milk is limited, they may be weaned much earlier without serious results.

Kids will eat a little hay and grain at an early age, and they should be provided with them. Alfalfa or clover hay should be given in a rack and the grain mixture in a trough. Arrangements should be made to keep the kids out of both the rack and the trough. A good grain ration for the kids consists of cracked corn, crushed or rolled oats, and bran mixed in the proportion of one part cracked corn, one part crushed or rolled oats, and one-half part bran. They should be allowed as much as they will clean up during the 24-hour period until they are eating one-half pound a day. All grain that is not eaten should be removed from the trough each day and fresh grain provided, as kids are very delicate in their eating habits.

If the kids are fed by hand, they can either be given the milk from a bottle with a nipple or a tank with a number of nipples attached, or they may be fed from pans. Most kids can easily be taught to drink from a pan or trough, and this system is less troublesome. Some kids, however, are very slow in learning to drink and do much better when fed from a bottle. Cleanliness is absolutely essential for the successful raising of kids. The pans, pails, bottles, and nipples should be kept clean. After the kids are a few weeks old and have learned to drink, they can be fed from a galvanized-iron trough. Care should be taken, however, to see that each kid receives its share of the milk.

Kids are very playful creatures and require considerable exercise. If they are kept in a small enclosure, it is a good plan to put a box from 18 to 20 inches in height in the center, so that they may run and jump upon it. This will give them plenty of exercise, and they will have keen appetities. Pasture or browse should be afforded as early as possible.

Castration

All buck kids not to be kept or sold for breeding purposes should be castrated when they are from 10 days to 3 weeks of age. The older they are, the more severe the operation. The operation of castration is very simple and can be performed by the elastration or pincer methods or by cutting the lower third of the scrotum off and grasping above the testicles forcing them out so that they can be grasped and pulled away one at a time with the spermatic cord attached.

The elastration method is accomplished by expanding a rubber band by an instrument, which is released around the scrotum, above the testicles, stopping the flow of blood to the extremity below the band. The pincer method is performed by clamping pincers, the jaws of which do not come entirely together across the scrotum above the testicles. This pincer crushes the cord but does not sever the outside layers of skin. These are known as bloodless methods of castration.

In case the knife is used when the kids are more than 4 months of age, the cords should not be pulled out but scraped off just above the testicles. The wound should be bathed with some good disinfectant after the operation.

Buck kids should be separated from the doe kids when they are about 4 months of age. Doe kids come in heat when young, and the young bucks worry them a great deal if allowed to run with them. Occasionally doe kids become pregnant when they are only 4 to 5 months of age.

Marking

Each goat in the herd should be marked in some manner for identification. This may be done by the use of metal ear labels, by notching the ears, or by tatooing the ears. In some instances all three of these systems are used. When this is done, the kids' ears are notched as soon after birth as possible, and when they are from 3 to 6 months of age the ear label is inserted and the tatooing done. The ear label is only a fairly satisfactory method of marking and never should be used as a sole means of identification as the label is liable to be torn out. Care should always be taken to insert the label rather close to the head and far enough up into the ear to make it fairly tight.

Notching the ears can be done with the punch used for inserting the ear label. Notches on certain parts of the ears indicate certain numbers, the sum of the numbers represented by the notches being the number of the goat. Numbers up into the hundreds involve a rather complicated system, but they are not usually necessary in a small herd. To avoid a complex system, each crop of kids may be numbered from one upward. The notch system is especially valuable, as it not only serves as a means of identification but it is not always necessary to catch the goats to read their numbers. A person can stand at some distance, and if the goat is facing him the notches can be seen readily.

Tatooing on the inside of the ear is the most satisfactory method of marking goats. There are on the market tatooing instruments having adjustable numbers and letters, with which a combination containing 3 or 4 of either or both can be made. Some breeders tatoo their initials in one ear and a number in the other. Tattooing is an excellent method of recording the identity of goats as the numbers are easily read and when properly inserted are practically permanent. Special nonfading tattoo ink can be obtained from all livestock equipment houses. Care should be used to make sure the ink is rubbed well into the indentures made by the needles.

Dehorning

Mature goats may be dehorned safely. This is done best by sawing the horns off close to the head with a wire saw such as veterinarians use. The operation should be performed if possible when the weather is fairly cool and when flies are not troublesome. As soon as the horns are removed, apply a little pine tar to the wounds.

The horns on kids can be prevented from developing by using caustic soda or potash sticks, commercial horn removing preparations, or the disbudding iron. Regardless of the method used it is highly important to make sure that the kid to be disbudded actually requires disbudding; that is, be certain that the kid is not naturally hornless. To determine whether a kid has horn buds, the hair should be clipped closely from the top of the head where the horn buds would be expected. If two shiny hairless spots show up, the size of a pinhead or larger, and if the skin is tightly attached to the skull at these points, it is highly probable that the kid has horn buds. On a naturally hornless kid, the skin can be moved from side to side by pushing with the finger, as the skin is not attached. However, there is an enlargement at the point at which the horn would be attached to the skull. The most favorable time to disbud is the day after the kid is born, provided the kid is of normal vigor, and it has been determined that the kid has horn buds. The sooner the operation is performed the less developed the horn buds will be and the easier it is to stop their growth.

Caustic sticks of soda or potash may be obtained from the drug store. These should be used with care, as they may injure the skin of the person handling them. The stick caustic should be wrapped in a piece of paper to protect the fingers, leaving one end uncovered. Moisten the uncovered end and rub it on the horn buttons. Care should be taken to apply the caustic to the horn button only, but it should be blistered well. This is best effected by clipping the hair close to the head for some distance around the horn button and coating the surface with petrolatum, leaving the skin close to the horn button and the button itself free from the coating.

The caustic may then be applied to the uncoated portion without danger of its burning the remainder of the head or running into the eyes. The application should be made when the kids are from 2 to 5 days old.

The disbudding iron probably gives more uniformly successful results and is easier on both the kid and the operator than the other methods. A disbudding iron can be purchased from goat dairy supply firms or made by anyone handy with tools. It resembles a soldering iron with the tip sawed off. Irons, the ends of which are slightly concave, are preferable to irons sawed off with plain end, although these also give good results. For disbudding the iron should be heated so that at least 2 inches are cherry-red. Having two irons so that a fresh one is ready for the second horn bud accelerates the operation. For small doe kids a 7/8-inch (diameter) iron is sufficiently large, but for large does and especially buck kids a 1-inch iron is better. The iron should be centered on the horn buds, and applied with a rotary motion and light pressure, for from 5 to 10 seconds or more depending on the size and development of the horn buds. When the iron has burned enough the clean skull will show. It is important that the iron be a cherry-red heat, because at a lower temperature a longer time is required which is more exhausting to the kid. Unguentine or carbolated vaseline should be applied to each disc immediately after disbudding.

Care of the Hoofs

If goats are more or less confined and not allowed to run upon gravelly or rocky soil their hoofs grow out and should be trimmed. A goat should have its hoofs trimmed so that it will stand squarely on its feet. A sharp pruning or hoof knife is best for this operation. The horny edge of the hoof should be trimmed level with the soft tissue which comprises the sole, and if this tissue is overgrown or unbalanced it may also require a little trimming. This part of the hoof is sensitive and must be trimmed carefully and not too deeply. Excessive horny portions of the heel should be trimmed so that the entire foot will set squarely on the ground. If the hoof is overgrown and badly out of shape, it will be necessary to restore it gradually to normal shape by drawing it to form a little more at each trimming. The need for hoof trimming will vary with individual goats, but examination of the hoofs should be made at monthly intervals.

GOAT MEAT AND GOATSKINS

There has always been a rather general prejudice in this country against the use of goat meat as food. However, in some sections a great many goats of the milk type, especially kids, are consumed and are in demand. They are sold for slaughter when from 8 to 12 weeks of age. The flesh of young goats, or kids, is palatable and has a flavor suggesting lamb.

The prices of goats sold on the market for slaughter are always considerably less than those received for sheep. Goats do not fatten and carry flesh as sheep do.

The United States imports in normal times about 40,000,000 goatskins annually, so it would seem that there should be a ready market for all skins that could be produced. Skins from the shorthaired goats, such as the common type of American goat and the milk breeds, are the kind used in the manufacture of shoes, gloves, bookbindings, pocketbooks, and like articles. However, as a rule these skins have only a small commercial value.

TROUBLES WITH GOATS

Although considered very healthy, goats are subject to disease and have their troubles as well as any other animal. Goats are less subject to disease than sheep, but the two species are so closely allied that, in general, the treatment in cases of disease is the same for both. Since the diagnosis and treatment of diseases require special knowledge and experience, the services of a veterinarian should be obtained whenever disease problems arise.

A matter of great importance and one on which breeders lay considerable emphasis is the fact that goats are rarely affected with tuberculosis. When confined to close quarters with cows that have tuberculosis, they may, however, contract the disease. Goats that are in good condition are not very liable to contract disease, but some maladies may affect them if they are allowed to get in poor condition.

In the Federal meat inspection the cause of most of the condemnations for goats on both ante mortem and post mortem inspections is emaciation. Emaciation may be due to any one of a combination of factors such as stomach worms, flukes, tapeworms, and abortion. It is necessary, of course, to determine the cause before treatment can be administered.

Diseases and Minor Ailments

Brucellosis

This term covers infection due to germs belonging to the genus known as Brucella. Organisms of this class are responsible for brucellosis, also known as Bang's disease and infectious abortion, in cattle and other animals, Malta fever in goats, and undulant fever in man who contracts the disease directly or indirectly from infected animals or their products.

Brucellosis in goats is most frequently caused by the germ, Brucella melitensis. Signs of infection may vary considerably. Abortions are common in herds where the disease has been recently introduced as well as in young does from herds where infection has been present for a considerable time. Other symptoms occasionally observed are lameness, retarded milk secretions, and inflammation of the udder.

Suspicion as to the presence of brucellosis can be verified by tests of the animal's blood. In herds found to be infected, repeated tests are usually desirable. The test, known as the agglutination test, is the same as that commonly used for brucellosis, or Bang's disease, in cattle. Milk and milk products from infected animals are dangerous unless pasteurized or boiled. Persons caring for infected animals are exposed to the infection.

The chief method of prevention is frequent blood testing. Newly acquired animals should always be subjected to test, preferably by an authorized agent of the State, before they are added to healthy goat herds. This is especially desirable in goat dairies, and is mandatory in some States. The reacting animals should either be isolated pending replacement or slaughtered under veterinary supervision.

Abortion

Goats, like all other species of farm animals, sometimes abort. The abortion may be caused by infection, lack of some necessary element in the diet, or other factor about which little or nothing is known.

If several repeated abortions should occur in the herd, infection of some kind may be suspected. In such a case it would be advisable to have the aborting goats, or even the entire herd, blood-tested for Malta fever. Goats affected with this disease are apt to abort. Malta fever is not likely to appear among goats except in those restricted localities where the disease is known to exist. The test for Malta fever is the same as that for Bang's disease.

If a doe aborts she should be placed in a pen by herself, away from the herd, and kept isolated until discharges from the generative organs cease and recovery is complete.

The fetus and after birth, provided the latter has been expelled, should be disposed of in such a manner as to be inaccessible to the rest of the herd. Similar disposition should be made of the discharges from the genital organs and of contaminated bedding.

Pens in which abortive goats have been isolated should be well cleaned and disinfected before being used again.

Little can be done or is necessary in the way of treatment beyond attention to the comfort and nourishment of the animal. If the afterbirth is retained for more than 24 hours, the subcutaneous or intramuscular injection of diethylstilbestrol or estradiol diproprionate is recommended. This treatment produces contraction of the uterus which aids in the expulsion of fluids and eventual detachment of afterbirth.

Constipation

Constipation sometimes occurs, especially in the kids. Simple constipation may be due to digestive disturbances resulting from accumulations of poorly digested dry feed, lack of exercise, or gorging.

A change of diet and adequate exercise may serve to relieve this condition. When medication is required such simple drugs as Epsom salts or oil may usually be safely administered as a drench.

The dosage for mature stock is from 2 to 4 ounces of salts dissolved in 1 pint of warm water. Weanling kids should receive only half that dosage. Castor oil or raw linseed oil in place of Epsom salts will be effective, and the dosage should consist of the same number of liquid ounces.

Mastitis, or caked udder

When mastitis is present the udder usually feels hard and is hot and swollen, but an occasional case may be found in which there are flakes in the milk and very little swelling of the udder. The condition is caused very frequently by the presence of bacteria which multiply in the milk and tissues of the udder, and set up inflammatory changes. Injuries, excessive accumulation of milk in the udder, rough milking, chilling, and systemic derangements favor the development of the disease-producing germs. The diseased animal should be promptly removed from the herd and treated. Treatment consists in milking the animal thoroughly but gently every hour or two during the day. The application of hot towels or water as hot as the hand will stand for 20 minutes 4 to 5 times a day will also be of benefit.

Antibiotics and sulfonamides are also useful for intramammary injection in cases of chronic mastitis or parenterally in acute cases. If these drugs are injected through the teat canal then frequent stripping of the udder is not necessary. Treatment by use of antibiotics and sulfonamides should be administered by a competent veterinarian.

Sore Teats

This condition may be caused by the teeth of the kids, warty growths on the teats, or an injury. After the teats have been washed and dried, carbolated petrolatum should be applied.

Foot Rot

Unless properly managed, goats may have foot rot. The first evidence of this trouble to attract attention is a slight lameness, which rapidly becomes more marked. The foot will become swollen and warm to the touch. There is no specific treatment for this condition. A treatment may be successful under certain conditions and worthless under others. In a treatment sometimes used, the affected feet are first trimmed thoroughly so as to expose the seat of infection, and then soaked in a saturated solution of copper sulphate (2½ pounds to 1 gallon of water) for several minutes. The animal is removed to clean dry quarters and the copper sulphate treatment repeated, when necessary. Pine tar applied to the feet helps to promote healing after the infection has been controlled. Sulfonamides and antibiotics are also used in the treatment of foot rot.

Parasites

Goats and sheep become infested with about the same kinds of internal and external parasites, and are adversely affected in a similar manner. A detailed discussion of this subject is given in Farmers' Bulletin 1330, Parasites and Parasitic Diseases of Sheep, and only the more important aspects of the problem are discussed herein.

Goats are known to harbor different kinds of parasites, but those concerned in parasitic gastroenteritis cause the greatest economic loss. The most important of these are stomach worms, intestinal hairworms, and nodular worms. Heavy infestations of the common stomach worm produce a severe anemia; stomach hairworms cause an inflamation of the lining of the fourth or true stomach, resulting in gastritis, diarrhea, and loss of appetite. The effects of intestinal hairworm infestations are similar to those caused by stomach hairworms, except that the inflammation is in the small intestine and is known as parasitic enteritis. Nodular worms may produce somewhat similar effects in the large intestine. Emaciation and death of kids and adult goats may result from heavy infestations of one or more of these parasites, unless measures are promptly taken to expel a significant proportion of the worms. Even if death losses do not result from parasitic infestations, there may be serious effects on growth, interference with milk production, and interruptions in breeding activities. Other internal parasites, such as liver flukes, tapeworms, lungworms, and coccidia, also can be troublesome to goats. Certain external parasites also are injurious but, in general, are considered of lesser importance.

Phenothiazine is the most effective drug that can be used for the removal of internal parasites from goats. This drug should be given in doses of 35 to 40 grams (about 1 1/3 ounces) to adult goats, and 20 grams (2/3 ounce) to kids under 6 months of age or 60 pounds or less in weight. Treatment with phenothiazine twice a year is recommended in cases where parasitism tends to be troublesome. More frequent treatments may be given if necessary. If goats are in production, the milk should be discarded, or used for other than human consumption, for a period of 4 days immediately following treatment, as phenothiazine imparts a pink discoloration to the milk for a few days after medication.

Phenothiazine may be given as a drench or in capsule. Animals may be treated individually or in groups by mixing the proper amount of the drug in their feed. This method is not recommended, however, for goats in production. In order to obtain an accurate diagnosis, to assure proper dosage, and to avoid injury to the animals, the treatment should be given by, or under the supervision of, a veterinarian.

Other chemicals, such as copper sulphate, nicotine sulphate, a combination of these, or tetrachloroethylene, are used to treat worm parasitism in goats, but none of these is more generally useful than phenothiazine except perhaps in the case of animals in production. Farmers' Bulletin 1330 contains further details on these and other treatments.

Measures other than specific medication can play an important part in effective control of goat parasites. A wide range and dry, hillside pastures tend to prevent parasitic infestation, whereas small, wet low-lying pastures favor the spread of parasites. Enclosures free from vegetation are not as dangerous as lush pastures. Cleaning out the manure frequently and thoroughly is another aid in keeping enclosures safe. Pasture rotation is an important control measure. The longer the pastures are rested the greater is the destruction of the free-living stages of the parasites. If it is not feasible to use these aids for parasite control one must resort to periodic medication with phenothiazine or other antiparasitic drugs.

Lice

Goats infested with lice may be treated by dipping, spraying, washing, or dusting with suitable insecticides. The method of choice will depend upon the number of animals to be treated, the insecticide used, prevailing weather conditions, and available facilities. Washing and dusting are probably the most practical methods for most dairy herds, the latter being particularly useful in cold weather. Spraying and dipping are very effective, but they are generally feasible only when large numbers of animals are to be treated. Whatever method is selected, however, all goats in the herd should be treated regardless of the number of animals infested. It may be noted that clipping long-haired goats discourages lice and is an excellent sanitary measure as well.

Suitable dusting powders may be prepared by thoroughly mixing 3 ounces of derris or cube powder (containing 5 percent of rotenone) or 2 ounces of methoxychlor (50 percent wettable powder) with 2 pounds of talc, pyrophyllite, or other similar diluent. The mixtures must be well rubbed into the hair over the entire body surface. Ordinarily, 1 or 2 ounces is sufficient for a single application which can usually be relied upon to protect the animals from serious reinfestation for at least 3 or 4 weeks.

Rotenone wash, or dip, may be prepared by dissolving 3 ounces of soap flakes in 1 gallon of water and adding 12 ounces of derris or cube powder (containing 5 percent of rotenone). The mixture should be prepared just before use, and it should be kept well stirred at all times.

A dip or wash containing 0.5 percent of methoxychlor is also effective against lice. A suitable suspension may be prepared by thoroughly mixing 4 ounces of 50-percent wettable methoxychlor powder in 3 gallons of water. The addition of an ounce of soap flakes to the water makes the wash easier to apply.

These washes are suitable for use during any season of the year except in extremely cold weather. Apply them with a brush or a cloth, spreading a thin, even coating over the entire body surface. Avoid contaminating feed, utensils, and drinking water with these preparations; do not allow pools of the mixtures to form from which the animals may drink; and do not allow the materials to drain over vegetation upon which the goats are permitted to graze.

Other chlorinated hydrocarbon insecticides such as DDT, BHC, toxaphene, and chlordane are also useful in concentrations similar to those of methoxychlor, but they should not be used on or around dairy animals in production since they are eliminated partly in the milk. A more complete discussion of methods of controlling lice may be found in Department Leaflet 308.

SWINE

Swine producers who use sound practices of breeding, feeding, and management usually make a profit.

If you are planning to raise hogs, you should begin by finding out if a supply of feed is available. Your farm should produce abundant feed or be in a cash-grain farming section. Your farm should be accessible to markets so that you can sell the hogs you raise.

NUMBER OF HOGS TO RAISE

Begin hog raising on a small scale. After you develop the necessary skills, gradually increase the herd size to fit your farm.

Expanding too quickly could lead to overstocking in feed, labor, equipment, or housing, or to neglect of other farm enterprises. Be careful to avoid conflicts of your farming schedule--farrowing versus planting or harvesting. These conflicts can cause serious losses in total farm income.

Once you determine the number of hogs that best fits your particular farm plan, stick to this number unless some major change--in size of farm or in cropping--indicates a larger or smaller herd. Most successful hog raisers produce at a uniform rate and concentrate on reducing waste and increasing efficiency.

In figuring the number of hogs you can raise on the feed available, include byproducts and water. Feeds that can be salvaged by hogs are skim milk, grain, field gleanings, unmarketable products from truck farms, and grain in droppings from fattening steers.

SELECTING BREEDING STOCK

Sows

Foundation sows for the herd should have meat-type body conformation, high milk production, and good weight for age. They should be physically sound. If production-tested sows are unavailable or prices are too high, select them on individual merit.

Desirable Conformation

The prospective brood sow should have a long body with a full spring of rib. The back should be uniform in width and the shoulders should be smooth. Along the topline, the back should be moderately arched and full and thick at the loin.

The sides should be long, deep and smooth; the ham should be wide and well developed, carrying down to within 2 inches of the hock. The jowl, underline, and base of the ham should be trim. The legs should be strong, of medium length, and should have good feet and strong short pasterns. The sow should have 12 to 14 good teats, open and without deformity.

Select breeding females from litters of 10 or more pigs out of sows that consistently produce large litters.

Profitable Life

The profitable life of a gilt or sow differs with the type of operation and with each farm.

Do not replace all gilts after their first litter. Instead, keep the best one-third to one-half of the gilts for a second litter. Having sows farrow two litters a year will give you more information for selecting young boars and gilts to be kept in the herd.

This system also permits sows to remain in the herd if they are superior to any of the gilts that would replace them. If distinctly superior, keep some of the best sows for a third or fourth litter.

When you select sows for additional litters, consider the number of pigs they produce and the weaning weight of the pigs. Also, consider the gilt's own growth and meat-type conformation.

Crossbred sows are often kept for their superior performance in prolificacy, milk production, and mothering ability.

Systematic crossbreeding programs are usually based on group standards of performance. These standards are maintained by hybrid vigor in the female line and the use of superior, production-tested males.

In order to obtain the maximum benefits from crossbreeding, all sows should be replaced after producing a planned number of litters. The principal advantages of this system are lower maintenance costs for gilts and higher sale value per pound as compared to older, heavier sows.

For maximum economy such a system usually includes a favorable arrangement--exchange or high-resale value--for keeping down the cost of boars.

BOARS

Selecting the right boar is even more important than selecting a sow or gilt because on most farms a boar is usually bred to several sows. Use production-tested meat-type boars, especially if they are as reasonable in price as untested boars.

Ignore minor defects in a boar unless the females have similar defects. The boar's good qualities should outweigh any major weaknesses in the sows.

Performance Information

If you must select a boar on type and appearance alone, wait until he is at least 6 months old. At this age, defects as well as desirable traits can more readily be observed than at younger ages.

Sometimes you must choose between a boar from a herd with high performance records and a boar of superior appearance from a herd with no performance record. When you make this choice, select one the basis of records rather than appearance.

Consider the boar's individuality and records of near relatives--dam, sisters, or brothers. The next most important qualities of a boar to consider are a moderately long body, good bone, and sound feet and legs. He should have masculine character, be smooth, not coarse, and have good muscular development in his ham and loin. His reproductive organs should be clearly visible and well developed.

Number of Boars

If the herd exceeds 15 sows and the sows are handled as a single group, use two or more boars. This will permit comparisons among the offspring of different boars and provide a way to select boar replacements on a progeny-test basis.

Avoid breeding animals with ruptures of the navel, sexual abnormalities such as hermaphroditism and cryptorchidism, and scrotal ruptures.

Do not use animals from litters with pigs that have defects. A single defective pig should rule out the selection of full sisters and brothers as breeders.

A boar should not be used for breeding until he is 8 months old. Keep a superior boar as long as he will fit into the breeding plan. Avoid close inbreeding such as parent-offspring or full brother-sister matings.

Crossbred Stock

Crossbred pigs have some advantages over their purebred parents. Crosses of lines or breeds usually improve prolificacy, survival, growth rate, and feed efficiency of pigs, and milk production of sows.

Two breeding plans for obtaining maximum benefits of hybrid vigor are--

* Rotational crossbreeding. It consists of using purebred sires of three or more breeds in a regular sequence or rotation. For example, females of breed A are mated to males of breed B, replacement females of AB cross are mated to breed C males and females from this mating (ABC) are mated to breed A males. This sequence is repeated as long as it gives satisfactory results.

* Crossbreeding, and rotating unrelated lines within a purebreed have similar effects. Rotating lines usually results in less vigor than a breed cross but produces greater uniformity.

The improvement obtained under either system depends on the genetic merit and the combining value of the stocks used.

Breed associations, State and Federal experiment stations, and extension services sponsor programs for evaluating hog performance and quality. They also help hog breeders find superior breeding stock.

FEEDS

Swine are fed chiefly cereal grains and their byproducts. To these are added protein and other supplements to provide a complete ration. This ration must contain proteins, carbohydrates, fats, minerals, and vitamins.

Grain

Corn is the staple grain used for feeding hogs. For best results, supplement corn with protein, calcium, phosphorus, and pasture or legume hay. For growing or finishing pigs, mix ground or shelled corn with a protein-mineral supplement. Grinding corn for hogs is not economical unless you plan to use it in a complete mixed diet.

Little wheat is fed to livestock. However, it is worth about 3 to 5 percent more than corn as a hog feed.

Good, sound barley, weighing 46 pounds or more per bushel, is 90 to 95 percent as good as corn. Lighter weight indicates lower feeding value. Barley should be ground or crushed. Do not feed scabbed barley.

Rye seems less palatable to hogs than other grains. Feed it ground with corn, wheat, or barley. Rye is dangerous if it contains ergot. Do not feed rye to pregnant sows; the ergot it may contain induces miscarriages.

Oats differ in feeding value--on the basis of percentage of hulls. The hulls determine weight per bushel. You can use oats as a replacement for corn--up to one-fourth of the diet. Ground oats equals the replaced corn in feeding value, pound for pound.

Oats is a better feed for growing pigs and brood sows than for market hogs. Because oats has a high fiber content, it retards excessive fat. You may want to use oats in the final stage of finishing market hogs.

Grain sorghums are nearly equal to corn as swine feed. They are slightly higher in protein content but lower in fat. Thresh sorghum for swine. Grinding grain sorghum seldom pays unless it is handfed.

Rice is rarely fed to swine unless it is damaged, low-grade, or exceptionally cheap. It is generally worth about 85 percent as much as corn.

Grain Substitutes

If your farm is located in an area where grains are not the most plentiful feed crops, you can substitute other feeds in the ration.

* Cull or surplus potatoes are occasionally fed to swine. Use potatoes--they should be cooked--only partially to replace the grain portion of the diet. For best results feed no more than 4 pounds of potatoes per pound of concentrates.

* Yams or sweetpotatoes are fed to swine principally in the South. There, yams usually outyield corn. Their disadvantages are high labor cost and low protein, calcium, and phosphorus content. They may be fed cooked, dehydrated, or raw.

Often, yams are harvested by grazing or hogging-off. For best results supplement yams with about one-third to one-half of the usual allotment of grain, plus protein and minerals.

* Molasses, when sufficiently cheap, can replace part of the grain in swine diets. Molasses and sugar are used in pelleted feeds and starter diets for baby pigs.

Root crops--mangels and turnips--are usually relished by swine. They are not economical to feed. Good legume pasture or hay is more efficient.

Silage is not suited for growing-finishing pigs. However, when properly supplemented with concentrates, silage is a good feed for pregnant sows. It costs less than conventional all-concentrate gestation diets.

Prosco or hog millet is grown mainly in the extreme northern section of the West North Central States. It is worth from 85 to 100 percent of the value of corn.

Many grain byproducts are used to feed swine either because of special nutrient content or favorable prices. Some byproduct feeds are hominy and gluten meal from corn, "oat clippings" and feeding oatmeal, wheat bran shorts and middlings, barley, rye middlings, rice bran, and rice polish. For complete information on feeding value of these byproducts you should consult a textbook on feeds.

PROTEIN SUPPLEMENTS

Animal Protein

Byproducts of milk, cheese, meat, and fish are valuable protein supplements to grain.

The amount of liquid skim milk or buttermilk needed to balance a corn diet differs with size and age of the pigs. Weaning pigs (56 days old) need about 4 to 5 pounds of milk product to each pound of corn.

Decrease the milk to 3 pounds when pigs weigh 50 to 75 pounds; to 2½ pounds when they weigh 100 to 125 pounds; and to 1 or 2 pounds after they weigh 150 pounds.

You can reduce the amount of liquid skim milk or buttermilk by one-third to one-half if you feed barley, wheat, or corn, on good pasture. Feed 4 to 6 pounds milk per pound of corn for 25- to 30-pound pigs; 3 pounds of milk per pound of corn for 50- to 100-pound pigs; 1½ to 2 pounds milk per pound of corn for 100- to 200-pound pigs.

If barley or wheat replace corn or corn is fed on good pasture, reduce the amounts of milk by one-third to one-half.

Whey is worth about half as much as skim milk. If you feed whey with corn or barley, also feed a vegetable protein concentrate--linseed meal, soybean meal, or cottonseed meal.

Condensed or dried whey, skim milk, and buttermilk are good protein feeds. They are generally priced too high for economical swine feeding, except in starter diets for early weaning or creep-feeding baby pigs.

Use meat scrap and tankage as standards for evaluating other protein concentrates.

Meat or fish byproducts are most efficient in a trio-type supplement mixture. This mixture combines a legume hay or meal with protein concentrates from both animal and vegetable sources.

Vegetable Protein

Soybean oilmeal is satisfactory as the only protein supplement to grain if pigs are fed on good pasture with vitamin B_{12} and mineral supplements. The same applies to drylot feeding if a legume hay or meal is included in the diet.

Cottonseed meal alone is unsafe for unrestricted feeding to swine because of its free gossypol content. It should be fed in trio-type mixture or combined with animal byproducts.

Peanut oilmeal is a good source of protein for swine. If you feed it as the only protein source, add calcium to the ration or, you can feed peanut oilmeal with an equal amount of fishmeal, tankage, or meat scrap.

Corn and soybeans are often interplanted for grazing or hogging-off. However, raw soybeans are inferior to soybean oilmeal for all classes of swine.

Peanuts are grown in many sections of the South to be hogged-off. They produce soft pork but are usually an economical feed. Rate of gain may be increased by feeding a supplement such as tankage with peanuts, but this is usually not as economical as hogging off with only salt and calcium supplements.

Garbage

Garbage feeders produce more than 2 million market hogs annually. Sterilizing or cooking garbage to prevent spread of disease is a legal requirement in almost every State since the national outbreak of vesicular exanthema in 1952.

Garbage differs widely in feeding value. The difference is due to the amount of inedible refuse in the garbage.

Carcasses of garbage-fed hogs shrink more, dress out at slightly lower weights, and are softer than grain-fed hog carcasses. However, the low cost of the feed usually makes garbage feeding profitable.

Minerals

Minerals are necessary for good swine nutrition. The minerals most needed are salt, calcium, and phosphorus. Lesser amounts of potassium, sulfur, iron, and manganese also are required. Under normal conditions zinc, cobalt, copper, magnesium, and iodine are essential in only minute or trace amounts.

Practically all feeds contain minerals. The combination of feeds that you use determines the amount of extra minerals needed in a ration. Because pasture and harvested forages have a greater percentage of minerals than seeds and their byproducts, pigs fed on pasture require less extra minerals than pigs fed in a drylot. Animal protein concentrates are also rich sources of minerals.

Almost any mineral mixture that supplies the needs of swine and is palatable enough to be eaten freely is satisfactory. For example, a mixture of equal weights of steamed bonemeal, ground limestone (or air-slaked lime), and salt is palatable. It contains the major elements needed for supplementing grain feeds. Use trace-mineralized salt that will supply requirements of the minor elements.

Supply a mineral mixture to hogs in boxes or self-feeders where it will be dry and available at all times. It may be mixed with the protein part of the diet, or incorporated at about 1.5 percent into a complete mixed diet.

Where hogs are raised in barns or on feeding platforms, mineral supplements are important. Frequently it is profitable to design mineral mixtures to fit the diets of different ages and classes of swine.

Vitamins

Most feed combinations used for swine feeding are adequate in most of the essential vitamins.

Swine fed pasture or fresh green forage, get practically all the vitamins they need except D and B_{12}. If you cannot feed fresh forage, include dehydrated alfalfa meal or high-quality legume hay in the ration.

To supply vitamin D, add small quantities of A and D feeding oil or irradiated yeast to the diet. Or, expose the pigs to sunlight. To supply vitamin B_{12}, include an animal protein concentrate or a vitamin B_{12} supplement in the diet.

Antibiotics

Feeding small amounts of antibiotics to swine stimulates growth and slightly improves feed use. These drugs reduce the numbers of organisms that cause diarrhea and other digestive-system infections.

Antibiotics are most effective with animals under stress from infections of the digestive tract, with younger animals, and with animals whose diets have low nutritive value. The antibiotics that give the best results and are most widely used for swine feeding are chlortetracycline (Aureomycin), oxytetracycline (Terramycin), penicillin, and bacitracin.

Water

Hogs need a plentiful supply of water. The amount they drink depends on size, age, class of animal, and climate. A weanling pig (35 pounds) may drink about one-half gallon; a market hog (220 pounds), about 1 gallon; and a brood sow suckling a litter, about 5 gallons.

For watering troughs, allow a sow and litter (or 20 weanling pigs) at least 1 foot (on both sides) of trough space. The animals should receive all they want to drink at least two or three times a day.

A supply of running water or an automatic system is laborsaving. An automatic cup will take care of about as many hogs (4 sows and litters or 80 weanling pigs) as 4 feed of water trough.

FEEDING

Brood Sows

To do her job efficiently, a brood sow needs an adequate diet. Overfeeding is more harmful than underfeeding. Either practice may be as harmful as a severe diet deficiency.

Pregnant sows usually are handfed a complete mixed feed. Or, you can scatter ear or shelled corn to encourage exercise and put the ground part of the ration in troughs. If you feed this way, allow a gilt about 1 3/4 pounds of diet daily for each 100 pounds live weight if she is in a small lot, or 2 pounds if in a large lot. A comparable sow allowance is 1¼ to 1½ pounds of complete diet per 100 pounds of body weight.

The average gilt or sow requires about 3/4 ton of complete premixed diet for the gestation period (hand fed) and a lactation period (self fed) of 56 days.

In estimating feed requirements for a herd of swine, allow approximately 1 ton of feed for each litter of pigs reared to 56 days. This will provide feed for boars, creep feed for pigs, and an allowance for some delays in getting sows settled.

For self feeding during pregnancy, mix ground legume hay or other bulky feed to prevent excessive fattening of the sows. This practice reduces labor costs and produces more uniform conditions of the sows. However, more total pounds of feed are required in this system and, for economy, you will need a cheap source of bulky feed.

Another economical gestation diet for sows includes well-eared corn silage, a protein supplement, minerals, and vitamins.

Cooking and Soaking Feeds

Cooking does not improve the feed value of grains. However, potatoes, soybeans, field beans, and velvetbeans are improved by cooking.

The protection against spread of disease more than compensates for any slight decrease in feeding value due to cooking garbage.

When it is impractical to grind whole barley or oats or when corn becomes very hard and dry, these grains may be slightly improved in feeding value by soaking.

Methods of Feeding Pregnant Sows

Hand Fed

Feed	Pounds
Mixed Diet (concentrate)----------------------------	6
or	
Corn silage--	12
Corn silage supplement------------------------------	1
Yellow, shelled corn (ground)-----------------------	1

Self Fed

Feed	Pounds
Mixed diet (high fiber)----------------------------	8

For 24 hours after farrowing give the sow water but no feed.

TABLE 1--Examples of gestation and lactation diets

Ingredient	Gestation			Lactation (complete)
	Hand fed (complete)	Silage (supplement)	Self fed (complete)	
	Percent	Percent	Percent	Percent
Yellow shelled corn (ground)--------	55.00		41.25	45.00
Corn cobs (ground)-----------------			35.00	
Oats (ground)----------------------	15.00			15.00
Standard Middlings-----------------				17.50
Molasses, liquid blackstrap--------			5.00	
Alfalfa Meal (dehydrated 17 percent)	15.00	15.00	5.00	
Tankage or meat and bone scraps-----	3.60	25.00	6.00	5.00
Fishmeal---------------------------	3.60			3.60
Soybean meal-----------------------	3.60	52.90	6.00	3.60
Linseed Meal-----------------------	2.40			7.50
Glauber's salt---------------------	.20			
Ground limestone-------------------	.40			
Bonemeal---------------------------	.40	4.00	1.00	.90
Salt, trace mineralized------------	.50	2.00	.50	.90
Antibiotic plus vitamin B_{12}----------	.30			.70
Vitamin B_{12}--------------------------		.50	.10	.30
Vitamin A and D supplement----------		.25	.05	
B-vitamin supplement---------------		.35	.10	
Total------------------------------	100.00	100.00	100.00	100.00

TABLE 2--Guide for preparing a premixed diet for pigs.

Age of Pigs	Approximate weight of pigs	Crude protein	Corn	Protein-mineral mixture
Weeks:	Pounds	Percent	Parts	Parts
8 to 14-----------	30 to 90	16	75	25
14 to 20-----------	90 to 160	14	83	17
20 to 25-----------	160 to 225	12	92	8

On the second day start her at about $2\frac{1}{4}$ to $2\frac{1}{2}$ pounds of feed and increase the ration each day. She should be on full feed, about 10 to 12 pounds, when the pigs are a week to 10 days old. As soon as she is on full feed, the sow may be self fed.

If a sow becomes constipated or suffers digestive upset, she may fail to come into milk or the milk may disagree with the pigs. For mild constipation, give a warm slop of wheat bran or of the regular diet, containing a tablespoon of Epsom salt or Glauber salt.

In cases of severe constipation or complete milk failure, call a veterinarian. Proper medication may save the pigs and the sow.

If orphaned pigs have received colostrum for a day or two before the death of the sow, they are fairly easy to rear. You can feed them with a bottle and nipple or a shallow pan.

Without colostrum very rigid sanitation is needed to save the pigs. Use whole cow's milk or goat's milk as a substitute for sow's milk. Commercially prepared sow's milk substitutes, sometimes called synthetic milk, have nearly disappeared from the market but can be useful for feeding orphan pigs, if available.

The easiest way to rear orphan pigs is to put them on another sow that has extra functioning teats. This is practical only if the foster sow farrowed within a day or two of the natural dam.

Growing-Finishing Hogs

Pigs, from weaning to market, may be self fed either a free-choice diet or a complete premixed diet.

The free-choice method saves grinding and mixing costs. The disadvantages are a slightly lower rate of gain and less uniform carcass finish. For the best results with this system, the grain portion and the supplement should be as near the same in palatability as possible.

Feeding a complete, premixed diet increases cost per pound of diet--the cost of grinding and mixing. However, it increases rate of gain and improves feed efficiency. This increase is not always enough to overcome the added cost.

The premixed diet permits uniform distribution of additives and usually produces more uniform carcasses than if the hogs are fed a free-choice diet.

A further advantage of this diet is that it allows changes in ingredients. You can alter levels of fiber and protein according to needs for carcass quality in market hogs. The formulas in table 2 are suitable for feeding pigs 56 days old. You can feed them these mixtures until the pigs reach market weight of approximately 225 pounds.

This protein-mineral mixture may be self fed in a separate compartment with ground, shelled, or ear corn. Or, you can make it into a complete premixed diet by combining with the proper proportion of grain.

The amount of feed needed to add 100 pounds of live weight to a hog is important for economical production of pork. This amount is influenced by age, health, inheritance of the animal, quality and combination of feeds, and environment.

Feed efficiency has been improved by the breeders' emphasis on changing from fat type to meat type as well as by advances in feeding "know-how." For instance, the complete diet just listed, when fed to good meat-type weanlings, has consistently produced 100 pounds gain up to market weight of 225 pounds for less than 350 pounds of total diet. Since these records were compiled, a number of cases have been cited of less than 300 pounds of feed producing 100 pounds of live weight gain in hogs.

Hog Pastures

Good pastures can supply a large part of the protein, calcium, and vitamins needed by swine.

With advances in swine nutrition, we are less dependent on pasture for growing-finishing hogs. However, pigs, intended for feeding out on concrete or in a drylot, will do better if they have had access to abundant green grazing during their suckling period.

Proper pasture use benefits both pasture and animals. Grazing too closely harms the plants. Undergrazing allows plants to mature too much and lowers their digestibility and palatability.

Pastures differ widely in carrying capacity, the amount depending on the crop, soil fertility, and climate. A fair-to-good pasture may carry five to fifteen 100-pound hogs per acre.

Hogs on pasture distribute manure uniformly. This saves the expense of removing and distributing manure--a considerable cost in platform feeding.

Pastures are more valuable for the breeding herd than for other classes of swine. The feed requirements of pregnant sows can be nearly filled by pasture under ideal conditions. Normally, you can count on grazing to replace one-third to two-thirds of a gestation diet.

Pig-Eating Sows

Killing and eating pigs is most often seen among animals that are nervous and excitable. Occasionally these sows eat one or more pigs. Some causes of pig eating are extreme heat, excessive pain in difficult or protracted labor, or loud noises.

Pig eating also occurs among sows having diet deficiencies or suffering from acute constipation due to faulty feeding or management. Although you cannot always prevent pig eating, good feeding and management should reduce it to a minimum.

Permanent Pastures

In most hog-growing sections, farmers plan to keep hogs mainly on permanent pastures.

Place only a limited number of hogs on permanent pasture. Allow the pasture enough growth to produce a crop of hay.

Plants used for permanent pastures are alfalfa, Ladino, red clover, alsike, white clover, bluegrass, bur clover, bermudagrass, lespedeza, carpetgrass, crabgrass, and Dallis grass.

The first six are used in the northern half of the United States. Bluegrass and white clover often are grown together. Timothy often is grown with red clover. The other plants are grown in the South.

Of all the permanent pasture plants alfalfa and Ladino are preferred by hog raisers. Where these plants thrive, no other permanent pasture is necessary.

Feeder Pigs

Larger farms, specialization, and laborsaving systems have increased the demand for feeder pigs. Many grain producers can fit a large-scale feeding operation into their program. However, they cannot devote enough time to manage a breeding and farrowing system profitably.

Weanling pigs 6 to 10 weeks old weighing 30 to 50 pounds usually are sold as feeders. Garbage feeders, drug manufacturers, and farmers who wish to graze or "hog-off" crops usually buy larger pigs, up to 120 pounds.

Most of the demand is from the Corn Belt and small grain areas. However, the Southern States have increased their swine-feeding operations and are competing for feeder pigs.

Many areas grow abundant grazing and forage crops but produce only enough grain for breeding stock on good pasture. Whenever these conditions exist and you apply approved methods of breeding, feeding, and management, producing feeder pigs should be profitable.

Temporary Pastures

You can use temporary pastures on nearly every hog farm.

Every barnyard and small lot where hogs are kept should be disked and seeded at least once a year. Disking once a year--or better twice a year--does not allow time for the permanent pasture plants to get established.

The grasses common in permanent pastures are not useful in temporary pastures where there are hogs enough to keep the pasture closely grazed.

The most common temporary pasture plants are rye, oats, wheat, rape, soybeans, and cowpeas. These plants are grown in most parts of the United States.

Seed temporary pastures heavier than a field for a grain crop. Sow rye in the fall.

In the northern areas, graze rye until it is covered by snow or made worthless by freezing. Rye may be grazed from early spring until hot weather. If the growth is rank, clip it with a mowing machine. Set the cutting bar as high as possible. In the South, rye may produce good grazing all winter.

In sections where winter oats is grown, the crop can be pastured the same way as rye. In the North, oats sown in the spring makes a good temporary pasture. The pasture period is short.

Rape is often sown with oats in the spring; Dwarf Essex is the variety of rape. You can seed rape from early spring until summer. When rye is 6 to 10 inches high, graze it heavily. It will keep growing and produce good, succulent feed.

Cowpeas and soybeans are sown in the spring. Sometimes they are planted together. Of the two, soybeans will usually make the best hog pasture. Select a variety that produces a large quantity of foliage and does well in your locality.

Turn in the hogs when the plants are 6 to 8 inches high. If the hogs eat the pasture down, take them out for a while to permit the plants to recover.

Dallis grass grows well in low, moist lands, makes a good growth in warm weather, and withstands close grazing well.

Sweetclover grows rapidly in good soil. Graze it heavily to keep the plants from becoming tough and fibrous.

MANAGING STOCK

Boars

To insure maximum usefulness of a boar--

He should have the run of a good-size lot or pasture, convenient to the breeding pen, but away from lots in which breeding sows are kept.

He should receive all the feed he will clean up twice daily during a heavy breeding season. Feed him the same diet listed for pregnant sows.

If he is used only lightly after a long or a heavy breeding season, reduce his feed to keep him in a strong, thrifty condition.

In hand-mating, allow a young boar to serve only one sow each day, except in emergencies. Limit an aged boar to this same schedule if he is used through a long breeding season. A strong, vigorous boar may serve two sows a day when necessary.

Service on each of two consecutive days will increase average number of pigs born by about one pig per litter. Have your boars use a breeding crate at least enough so that they become accustomed to it. The crate is useful for mating females and males of different size.

Group mating is practiced where group standards are emphasized rather than individual excellence. Under a group system, run two or more boars with a group of sows to settle all the sows as quickly as possible.

The advantages of group mating are maximum litter size and minimum labor. Heavy service for short periods, followed by rest, apparently is not harmful to boars.

Sows

Select only growthy, well-developed gilts for breeding. They can be safely bred at 8 months of age. Gilts bred too young may produce fewer and smaller pigs. Also, they may have more trouble at farrowing and fail to grow out well after weaning their first litters.

Under the gilt-litter system, all gilts are finished for market immediately after weaning their first litters. Immediate marketing avoids the lower price usually paid for older, heavier sows.

Under other systems, gilts are kept for a definite number of additional litters, or for as long as they produce profitable litters.

If they are fed an adequate diet, pregnant gilts have little interruption in their growth.

Sows may produce two litters a year up to 6 or 8 years of age, or even longer. Commercial producers frequently discard sows at earlier ages than 6 or 8 years. Purebred breeders usually retain the best females as long as they remain productive.

A sow usually will farrow in 112 to 115 days after she is bred. Sometimes she will farrow in 110 days or she may go a few days over 115. By keeping a careful service record you will know when to expect the pigs.

Care of Sows During Pregnancy

Breeding and pregnancy are the most critical events in profitable swine production. Sows that are too fat at breeding time have smaller litters than thrifty sows. For best results, the sow should be in good condition, neither thin nor excessively fat.

"Flushing," or increasing the ration, for 1 to 3 weeks before mating tends to increase ovulation and conception rates.

Most important during pregnancy are adequate nutrition, exercise, and protection from extreme cold or heat. Improper feeding may cause deaths among unborn pigs or poor survival of the newborn pigs. For information on feeding sows during pregnancy see page 241.

Care of Sows and Pigs at Farrowing

About 3 days before farrowing, move the sow to scrubbed, disinfected quarters. Wash her with soap and warm water, especially her teats. Place light bedding in the farrowing pen. You can use short hay or straw, peanut hulls, or shavings.

Reduce feed by one-third to one-half and watch for any signs of digestive upset or constipation.

Normal, healthy sows usually farrow without trouble. If possible, an attendant should be on hand to give any needed assistance. The assistance may be preventing pigs from chilling, warming them after chilling, or starting breathing in apparently lifeless pigs--by clearing the membrane covering the head and massaging or slapping the pig's sides.

After delivery, paint the navel cords with iodine. Clip the tips of the eight tusklike needle teeth, and weigh and earmark the pigs.

The sow needs no feed for 24 hours after farrowing; she should have water available. If at all possible, feed the sow in an enclosure separate from her pigs. This will prevent her from crippling or killing the pigs accidentally while her attention is centered on eating. It also aids in keeping the farrowing pen clean because droppings are usually voided during the feeding period.

Sows and Suckling Pigs

Some sows are not able to nurse all the pigs they bear in one litter. If the sow does not have a functioning teat for each pig, transfer pigs to a sow with a small litter. Make the change as quickly as possible.

Transferring pigs is rarely possible after more than 3 or 4 days, because teats that are not sucked dry up. Also the odors of the pigs must be masked until they are accepted by the foster dam. To do this put a little oil or some harmless ointment on both the sow's own and adopted pigs.

Unless newborn pigs have almost immediate access to the soil, you must plan a way to prevent anemia. Several procedures for preventing anemia are--

* Provide clean soil or sod;

* Spray or paint copperas (ferrous sulfate) solution on the sow's udder;

* Dose with iron tablets;

* Use intramuscular injections of iron-dextran compounds.

Increase the sow's ration gradually until she is on full feed--when pigs are a week old. Feed the pig a starter diet in a "creep." Litters from poor-milking sows are greatly benefited by creep feedings; litters from the better-milking sows do not eat enough to increase feed costs.

Pen the sow and litter separately for at least 1 week, preferably for 2 weeks.

Do not pen more than four sows and litters together under central farrowing house conditions. All the pigs should be within 1 week of the same age.

Limit the sows and pigs on one pasture to six sows with litters. These litters should be within 2 weeks of the same age.

Procedures that may cause stress in young pigs are castration, vaccination, weaning, and worming. Schedule these so that one stress effect wears off before the pig is subjected to another.

Unless male pigs are to be considered later for breeding, castrate them during the first 4 weeks. Pigs weaned at 4 weeks of age or less should be castrated at least 1 week before or after weaning. The operation should not follow cholera vaccination by less than 3 weeks.

Weaning

Most pigs are weaned at 5 to 8 weeks of age, under a 2-litter-per-year system. Reduce or cut off the sow's feed for 2 or 3 days before weaning to reduce milk flow and prevent udder trouble. Then remove the sow from the pigs, leaving the pigs in familiar quarters.

If a sow's udder appears too full, return her to the pigs for suckling; then, remove her immediately. A second return rarely is necessary, except with very heavy milkers.

A sow normally will come in heat 3 to 7 days after the pigs are weaned. She may be bred again at this time.

Recordkeeping

Every pig should be marked at farrowing time. The most satisfactory method is to notch the ears. Eartags of different kinds are used, but they tear out easily and the identity of the pig is lost.

Even if hogs are raised for market only, earmarking the pigs will help you select animals for the breeding herd. Reliable selection can be made only if the dam of the pig is known and her performance record is examined.

Small, sharp, side-cutting pliers do a good job of earnotching. For permanent marks, notch deeply enough to include a part of the cartilage of the ear. Notch the ears soon after the litter is farrowed, when wounds heal quickly.

Record every breeding date. If you know the farrowing dates, you will be ready to feed and care for the sow.

Sanitation

Results from the best methods of feeding and breeding will be lessened by faulty sanitation.

Keep farrowing houses and sleeping quarters clean. Change bedding frequently; do not let it become wet and foul.

The floors of the sleeping quarters become dusty. Dust is irritating to the lungs and may carry eggs of parasites. To reduce dust irritation clean the floors at least every 2 or 3 weeks; disinfect floors with a 3-percent solution of cresol. To make this, add 1 pint of cresol to 4 gallons of water.

Apply lime to pens and feeding places that are not plowed. The lime will aid in drying damp places and in disinfection. At least twice a year, disk all barnyards and lots or temporary pastures on which hogs are kept. If you plant pasture crops in these lots, the disking will be profitable in two ways.

Cooling Equipment

Shade

Hogs suffer greatly from heat and must have shade. Keep farrowing and individual hoghouses closed in hot weather to prevent hogs from lying in them. Hogs will seek shade even if they suffocate in it. Trees provide good shade if there are enough of them in a clump. Or, you can make a satisfactory shading structure with a framework about 4 feed high, made of posts or poles. Cover the top with hay, straw, or weeds to a depth of at least 2 feet. When dust accumulates under this shelter, wet the covering. The water will drip through to settle the dust and cool the air in the shelter. You can make permanent shelters from pipe, lumber, and conventional roofing materials.

Farrowing Quarters and Equipment

Farrowing quarters are variations of three basic patterns.

The conventional "square" pen should be at least 6 by 8 feet for a gilt and 8 by 8 feet for a sow.

The farrowing crate or stall should be 20 by 72 inches for a gilt; 24 by 84 inches for a sow. Provide an enclosed area, 18 inches wide on each side of the crate for the pigs.

An ideal temperature for the farrowing house is 55° to 65°F., if the house is adequately ventilated. Because a newborn pig chills easily, you should provide some heat in the protected resting area for at least 5 days.

The amount of heat needed differs. It may be supplied by infrared-heat lamps or electric hovers in cold climates. Use a 100- to 125-watt light bulb mounted in a metal reflector in warm climates. Because any type of heating device can cause fire, you should install heaters carefully.

Sometimes it is difficult to make the farrowing house temperature suit both sows and newborn pigs. Extreme heat and humidity may have worse effects on farrowing than extreme cold. The nervous, restless behavior of sows suffering from heat usually causes pig deaths from mashing.

Occasionally, a sow may be lost from heat prostration. In the warmer sections of this country avoid farrowing in midsummer unless you provide some method of cooling the sows.

Farrowing house plans suitable for a particular locality may be obtained through your State extension service, county agricultural agents, or farm adviser.

If the sows have been running on pasture, move them to clean, new pasture and allow them to farrow there. Wash the sows before you move them if they are encrusted with mud and filth. This method is suitable for fall farrowing in practically all States. It is also suitable for spring farrowing in the South.

Wallows and Sprinklers

A hog wallow made of concrete and located in a convenient shady place is a benefit in a hoglot. A mud wallow made by the hogs rooting a hole in the lot or pasture is a nuisance. It should be filled in.

It is impossible to keep a mud wallow sanitary. Hogs may drink the water that has become stagnant and foul.

The concrete wallow should hold 4 to 6 inches of water. Clean it frequently and refill with fresh water. To control lice, spray enough crude oil to form a thin layer on the water. Apply the spray about every 10 days.

If you feed hogs on concrete and a pressure water system is available, use fog-type sprinkler nozzles, such as those used in fuel oil burners, to cool the hogs.

HEALTH

Among the important health problems of hogs are cholera, erysipelas, brucellosis, tuberculosis, necrotic enteritis, atrophic rhinitis, swine influenza, and parasitic infestations.

Ask your veterinarian about the preferred times, methods, and number of vaccinations and other disease control measures needed to protect swine in your area.

Diseases

If you suspect that one of your animals is sick, ask your veterinarian about the proper treatment.

Because some livestock and poultry have diseases that can be transmitted to hogs, the danger of permitting hogs to eat carcasses outweighs the feeding value. Carcasses should be burned or buried.

Parasites

Parasites affect hogs of all ages and may cause death--particularly among small pigs--reduce vitality, and prevent best and most rapid development.

The most damaging internal parasites are large roundworms, kidney worms, thorn-headed worms, lungworms, and intestinal threadworms.

The principal external parasites are sarcoptic mange mites and sucking lice. Most of these species are found in practically all hog-raising areas.

Internal Parasites

Most swine parasites can be controlled by sanitation including--

- Clean, disinfected farrowing pens;
- Sows washed clean before farrowing;
- A "clean" trip to clean pastures for sows and their litters;
- Clean pastures for the pigs until they are at least 4 months old.

Internal parasites can also be controlled by feeding pigs exclusively on milk, skimmed milk, or whey for periods of 3 successive days at intervals of 2 weeks, or by feeding one of these daily instead of one grain feeding.

Pigs should be treated to control large roundworms at weaning and again about 2 months later. Use dry sodium fluoride--technical grade, tinted--at a concentration of 1 percent by weight, in dry, ground feed for 1 day.

Pigs should be slightly underfed the day before treatment. On the day of treatment, give them about two-thirds as much medicated feed as regular feed.

Ordinarily, no other treatments are necessary or advisable. The treatments should not be given to pregnant or lactating sows, or to any animals showing symptoms of gastroenteritis.

External Parasites

For treatment of mange mites and eradication of lice, several insecticides are safe and effective--lindane, toxaphene, malathion, methoxychlor, DDT, Bayer 21/199 (CO-RAL), and Ronnel.

All of these insecticides may be used as sprays. Use lindane dusts and DDT dusts and sprays only once. Use one of the other insecticides if you need to repeat treatment after 2 or 3 weeks.

Do not treat sick animals or those less than 3 months old with Bayer 21/199 (CO-RAL). Spray animals 3 to 6 months old only lightly. Market hogs should not be treated within 4 to 6 weeks of slaughter.

If you want to dust your animals use a DDT dust of 10 percent strength: Use lindane dust of 1 percent strength--only one time.

Guide for Mixing Sprays

INSECTICIDE FORMULATION	PERCENTAGE OF INSECTICIDE DESIRED IN SPRAY	AMOUNT OF FORMULATED TO MIX WITH WATER	
		100 GALLONS	5 GALLONS
METHOXYCHLOR:			
EC, 25 percent	0.5	2 gallons	13 ounces
WP, 50 percent	0.5	8 pounds	6½ ounces
LINDANE:			
EC, 20 percent	0.03	20 ounces	2 tablespoons
	0.05	1 quart	3 tablespoons
WP, 25 percent	0.03	1 pound	3 tablespoons
	0.05	1 2/3 pounds	5 tablespoons
TOXAPHENE:			
EC, 60 percent	0.5	5½ pints	4½ ounces
WP, 40 percent	0.5	10 pounds	8 ounces
DDT:			
EC, 25 percent	0.5	2 gallons	13 ounces
WP, 50 percent	0.5	8 pounds	6½ ounces
MALATHION:			
EC, 57 percent	0.5	1 gallon	6 ounces
WP, 25 percent	0.5	16 pounds	13 ounces
BAYER 21/199 (CO-RAL):			
WP, 25 percent	0.5	16 pounds	13 ounces
RONNEL (Korlan):			
EC, 24 percent	0.5	2 gallons	13 ounces
WP, 25 percent	0.5	16 pounds	13 ounces

POULTRY

Probably no phase of a bird's life is more frequently neglected than the period from the time the bird leaves the brooder house until it reaches maturity. Yet this is an extremely important period. If stunted during the growing period, the bird never amounts to much. This is equally true for pullets, cockerels, capons and turkeys. Therefore when you learn to handle growing stock, the first important step in poultry husbandry is mastered.

To take this step, have adequate buildings, equipment, proper range, a balanced ration and above all, good chicks.

The Range, Shelters and Equipment

The Range -- Provide a clean range -- one where no birds have run for at least a year, preferably two or three years. This is so necessary that when you cannot provide clean range, engage in a different project. One acre will support 300 growing chickens or 150 turkeys. However it is better to plan on one acre for each 100 birds, since birds must be moved at least three times during the growing season.

If an alfalfa or green sod range can be used, the growing cost may be cut about 20%. Also birds reared on a green range are healthier and grow more rapidly. When running water (either piped or in a stream) is available the labor of handling birds is reduced and the birds grow faster.

The Range Shelter -- When birds are fully feathered over their backs, it is time to move them to the range. If they can be roosted in a range shelter, they grow better than in a brooder house. Besides, a range shelter is easier to ventilate and costs less to maintain.

A shelter need not be fancy or expensive. It is merely roosts with a roof, wire sides and wire floor. Space roosts about 12 inches apart. Have the comb of the roof about five feet and the eaves about 2½ feet from the ground. The size of the shelter depends upon the size of the flock. Pullets and capons will need 8 to 10 inches linear roost room. Turkeys will need 9 to 12 inches. Thus a 7 ft. x 8 ft. shelter will accommodate 100 pullets or 50 turkeys.

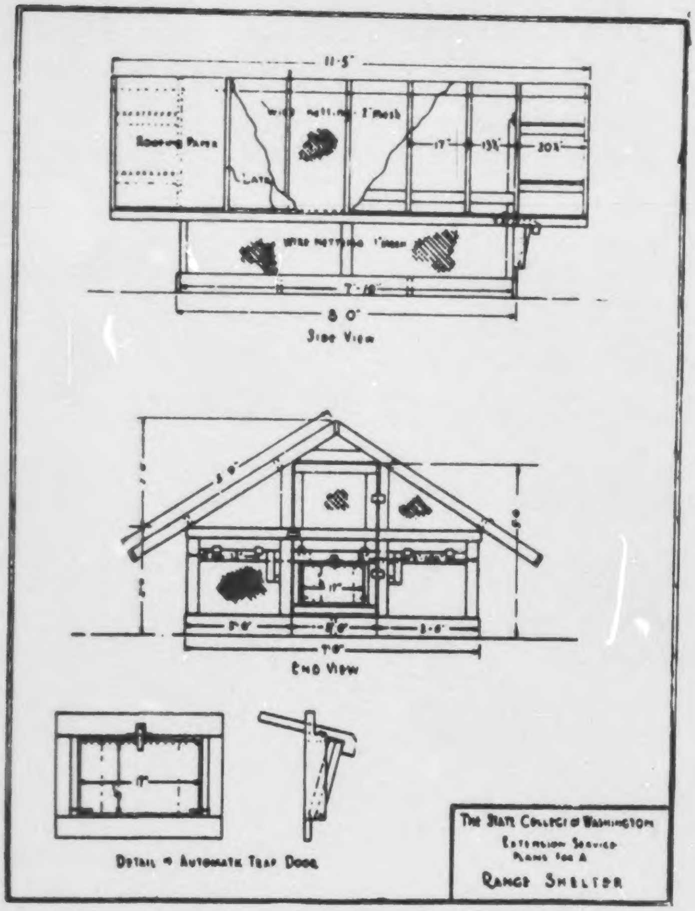

11'-5"
Wire netting 1" mesh
Roosting Poles
Lath
17"
13½"
20½"
Wire netting 1" mesh
7'-10"
8'-0"
Side View
End View
11"
Detail of Automatic Trap Door
The State College of Washington
Extension Service
Plans for A
Range Shelter

FIGURE 1.—Plans for Range Shelter.

Range Shade -- If the birds have shade, they grow faster, feather better and do not sunburn. However don't let your birds hang around a shelterbelt or patches of underbrush where birds have run year after year. Sooner or later sickness occurs unless the ground is cleaned up. If no natural shade is available, make a shade or plant corn or sunflowers in rows to provide shade.

Range Equipment -- Make range feeders and waterers movable; covered to provide shade and protection from weather.

FEEDING GROWING STOCK

Feeding Systems--growing birds do not need as rich a diet as they did when younger. However they need a ration which will supply body building and energy materials. In addition they must have plenty of clean, cool water. To provide feed requirements any one of several systems may be used;

1. Commercial or home mixed growing mash before them in hoppers at all times plus morning and evening whole grain feedings.
    a. Give the amount of grain that will be cleaned up in an hour.
    b. If fed on the ground, choose a clean spot each time.
2. Growing mash (commercial or home mixed) plus whole grains fed in separate hoppers. Keep both feeds before the birds at all times. This is called "cafeteria style."
3. Milk plus whole grains plus green feed. To meet the bird's needs, 3 gallons of skim milk or buttermilk must be consumed daily per 100 birds. Keep the grain before them at all times in hoppers. With this system it is very necessary that the range be green. If not, feed additional greens daily.

Growing Mash Formulas -- There are many good formulas for mixing growing mashes. The following have proven satisfactory:

Growing Mash

	Ground wheat	30 pounds
	Ground oats	20 pounds
	Ground corn (yellow)	15 pounds
	Ground barley	10 pounds
(1)	Meat scrap (50% protein)	10 pounds
	Dry Skimmed milk	5 pounds
	Alfalfa leaf meal	5 pounds
	Bone meal	2 pounds
	Oyster shell (ground)	2 pounds
	Salt	1 pound
(2)	Cod liver oil	1 pint
	Manganese Sulphate	4/10 ounce
	Total	100 pounds

When meat scrap and dry skim milk cannot be purchased and liquid skim or buttermilk is not available, substitute 2 pounds of dried whey plus 5 pounds of cottonseed meal and 8 pounds of soy bean meal.

When a guaranteed cod liver or other fish oil of known Vitamin D content is not available, substitute 2.4 ounces of Vitamin D supplement having 400 A.O.A.C. chick units.

Proportions of Feed-Stuffs -- It is just as important to have your birds eat the right proportions of their feeds as it is to have these feeds balanced. For example, if the birds fill up on grain and eat no growing mash, they get fat and grow slowly. On the other hand, let a pullet eat only mash, she will comb up and lay before she gains body maturity. Table 1 gives an idea of the proportions of mash and grain which birds should eat at various ages.

Table 1--Proportions of Mash to Grain Consumption

Age in Weeks	% Mash	% Grain
6	95	5
8	90	10
10	80	20
12	70	30
14	60	40
16	50	50
18	40	60
20	30	70
22 to maturity	25	75

Growth to Feed Consumption -- Another important feeding factor is the relation of rate of growth to amount of feed eaten. To get this, record the average weight of the flock and of feeds eaten. You are not expected to weigh each bird weekly to ascertain rate of gain. To do this would be foolish and time consuming. But weigh a sample of birds each week. At the beginning of the growing season mark five average birds in some way so that they can be easily spotted. Don't pick five extra large birds or runts.

Some poultrymen mark birds by daubing paint across their shoulders. This method requires repainting whenever birds grow new feathers. If leg banded, watch the legs. A growing chick may soon outgrow its band. This will cause sore legs, even crippled birds. Put the same five birds into a crate and weigh each week. Divide their total weight by 5, giving a fairly accurate average weight for the entire flock. Catching at night while roosting is a simple way to handle the problem.

Though the feed formulas and proportions on pages 260 and 261 are not ideal for all environments, the figures will serve as a guide. In the Temperate Zone with its long growing days, birds usually eat more and make faster gains.

Young Stock Diseases

Since a special chapter is devoted to diseases, only mention of the troubles affecting growing stock will be given here. Growing chicks are apt to have coccidiosis, colds, fowl paralysis, perosis, vitamin deficiencies and troubles caused by an infestation of worms, mites or other parasites. Also growing turkeys are subject to blackhead.

As with all diseases, spot a sick bird at once, take it away from the flock and correct the cause of the disease.

Range Management

There is more to handling growing stock than giving them shelter and feed. A good poultryman watches his birds all the time. He heads off dangers and anticipates the birds' needs.

First Nights in a Range Shelter -- If birds have come from a warm brooder house, shield them from drafts and cold winds. They must be kept from crowding and taught to use their new roosts.

Storms -- Until birds learn to run to shelter, see that they are driven in before a storm. Be sure the door has not blown shut. Keeping birds out in a storm may cause heavy losses.

After a storm, check the range. Fill up or drain puddles. Stagnant water causes sickness.

At all times watch for any dead chicks or gophers on the range. Nothing sickens birds quicker than eating decaying flesh.

Enemies on Range -- One or two species of hawks sometimes prey upon poultry on the range. Several poles may be set up with strings or wire stretched between the poles. String bits of shiny metal on the strings, for example, old lids from fruit jars. The metal catching the sunlight scares the hawks away. At night lock birds securely in the range shelter. If small animals like minks or weasels bother, a tight, inch-mesh wire under the roosts keeps them out. When young turkeys roost on exposed perches, it is well to keep a lighted lantern on a pole near the roosts. If coyotes are a menace, keep birds in their shelters until after daylight. A tight fence about open roosts helps. With a large flock of birds roosting in the open, you may find it necessary to sleep in a tent near them.

Dried Out or Dirty Range -- You are advised to change range at least 3 times during the growing season. Yet no management detail requires your judgment and common sense as much as the decision of when to move birds. If the birds eat the green feed down to the roots, a vitamin A deficiency may show up. Then look out for colds, swollen eyes and slow growth. During a dry season when the range dries up, move birds oftener than when the range stays green.

Hot Nights -- One hot night may ruin the flock. If hot nights occur, see that ventilation is adjusted to meet the condition.

Feeding -- The real test of a poultryman is how he manages the feeding problem. What kind of feed is needed, the proportions, and the amounts, have already been discussed. Yet under Range Management something more should be said.

The good poultryman watches the feeders. Are birds wasting feed? Are birds choosy, selecting some ingredients and leaving others? Did last night's rain wet the feed causing the mash to sour? Does the wind sometimes blow the mash away? Do the birds go on the roosts at night with full crops? A good poultryman checks all of these things each day so he can correct faults at once.

Uneven Development -- Even though you feed a balanced ration and provide plenty of feeder space, all birds do not develop uniformly. If a farmer has a small number of birds, little can be done about this. But with a greater number, divide into early maturing, medium and slow maturing birds. Dividing sizes, gives a more uniform bunch of birds at the end of the project. Give the birds which grow too fast, more grain and less mash than suggested in table 1. Give the slow birds more mash and less grain than called for in the schedule. For medium birds, follow the schedule.

CAPONS AND CAPONIZING

A capon is an unsexed male bird of the dual purpose or heavy breeds. Plymouth Rocks, New Hampshires, Rhode Island Reds, Wyandottes and Orpingtons make excellent capons. Altered Leghorns are not accepted as capons.

Because capons produce meat having better flavor and quality than unaltered males do, capons bring a better price and are therefore profitable to raise.

When to Caponize--The earlier the operation is performed the less the birds suffer from shock or set back. Therefore operate as soon as sex can be distinguished. With dual purpose birds this can be done by the time the birds are from 8 to 10 weeks old or when they weigh from 1 to 1½ pounds.

Starving--In order to perform the operation successfully starve the birds for 24 hours. They may have water to drink. This helps to clean out the intestinal tract. When starving, place them in a slat or wire bottomed crate off the ground where they can't pick up anything. A shipping crate turned upside down works well.

The Operation

The instruments--There are many sets of instruments. No matter which kind, the set must have a knife to make the incision; a spreader to hold open the cut; a hook to tear the membrane covering the intestines; a blunt instrument to press back the intestines out of the operator's way and an extractor to remove the testicle. An extractor made like a forceps does a more complete job than one shaped like a spoon.

The operating table--Use either a box or a barrel for an operating table. Place an old magazine under the bird. Turn a clean page for each bird. Remember that this is a major operation, thus cleanliness is important. Place the instruments in a disinfectant solution when not in use during the operation. A 5% Lysol or carbolic acid solution works well.

Tying down the bird--Place a nail on either side of the barrel or operating table. Tie a long shoe string to the rear nail. Then wrap the string around both wings of the bird lying on its right side on the operating table. Place a "half hitch" around the bird's shanks. Draw the string very tightly and tie to the front nail.

The operation--After removing the feathers in front of the thigh, make an incision or cut between the last two ribs. Be careful to hold the heavy hip muscle back over the thigh to prevent cutting into the muscle and causing bleeding. In making the incision, do not cut into the rib joint. This causes such a wide opening that the spreader will not stay in place. Also do not cut too near the back bone. Bleeding results and the lungs are punctured. Now place the spreader in the incision.

If the cut has been made correctly and the bird properly starved, as soon as the membrane covering the intestines is torn, the testicle may be seen. It is creamy yellow, about the size of a grain of wheat or a small bean and lies close to the back bone. Right back of it is a large artery which supplies the lower half of the bird's body with blood. Be very careful in extracting the testicle. Beginners should not attempt to extract both testicles from one side. Remove the left one first. Clamp the extractor firmly around the testicle. Then turn the instrument around completely several times. This draws out the testicle cord, insuring complete extraction and prevents bleeding. Cut the cord. Now turn the bird over and repeat the process on the right side. It is necessary to sew the incision. As soon as the bird is released the hip muscle slides over the wound.

Care after operation--After the operation, put the birds in a clean place where they cannot fly. Feed them soft feeds and milk for several days. Watch for "wind puffs"--that is, air gathering under the skin. If "wind puffs" occur, puncture the skin and press out the air. Disinfect the surface of the skin. Sometimes "wind puffs" have to be opened several times.

Care and Feeding Growing Capons--For this part of the project, study pages 258 - 263; all growing stock are handled in the same manner.

Fattening Capons--In most instances capons need no fattening. When they have gained their growth, they are ready to market. But if they do require fattening, do not pen them up for more than 10 days before killing. Feed them 4 or 5 times daily, the amount which they will clean up in an hour. Then remove the feeders and darken the room so that the birds will rest until the next feeding time. The feed may consist of any mixture of grains to which is added some alfalfa leaves and flour or middlings. Then add enough milk or water to make a batter-like mixture.

BABY CHICKS

The care and management of baby chicks is an exacting task. Do not attempt to raise them until you are thoroughly familiar with the job of growing young stock. Further you should not tackle the raising of chicks until you can have complete charge of them.

To raise chicks successfully you must havean adequate brooder house; a good brooder stove or the equivalent; adequate brooder house equipment; a complete and adequate ration and good chicks.

The Brooder House

There are two types of brooder houses which are generally used in the U.S.,(1) the shed roof type and (2) the arch roofed type.

The essentials of a good brooder house are:

1. Enough floor space--Allow 1 square foot per chick. At least 1 square foot is needed for every 2 chicks from one to eight weeks. Then double the floor space. Since chicks still need heat, it is better to start with 1 square foot per chick.

2. A well ventilated room--Although chicks need uniform heat, the room must be ventilated in order to keep the floor dry and the chicks healthy. Thoroughly study the ventilators in any brooder house plans.

3. The house needs a floor--Never put chicks on a dirt floor, especially if chicks have been raised on it before. A portable brooder house needs a wooden floor.

The Brooder Stove and Hover

When brooding chicks, remember that when a mother hen hovers them, she sits over them. Thus, if their backs are warm, they are warm. Therefore a good brooder stove with hover, supplies the heat above the chicks. The kind of fuel used is immaterial so long as the source of heat is steady. Run the brooder stove several days before the chicks arrive. If you use an old stove, check all working parts.

The type of hover is also unimportant so long as each chick has 7 square inches hover space. Since the space should be doubled at 8 weeks, it is best to start with a generous hover.

A home made brooder may be built. Even the fireless brooder works in the brooder room if it has a steady temperature of 75° to 80°.

Fire box--The fire box may be made from an old oil barrel, heating stove, or it may be a brick or concrete fire box. The main thing is to have the fire box fitted with a tight door so that the fuel burns slowly. Place the fire box at least 18" below the surface of the ground with about a foot dug at either side of it. Fill the entire space, around and over the fire box, with rocks or bricks and sand. Start the fire at least 4 or 5 days before the chicks or poults arrive in order to have the sand and rocks thoroughly heated. Once hot, the temperature at the edge of the hover will remain constant. The temperature will not drop even after the firing of the stove has been discontinued for 36 hours.

Be sure the fire box is placed back from the sill of the house to avoid any fire risk.

Have an additional door to give additional protection. The door prevents draughts and too rapid burning of fuel. When burning wood a grate is not needed, but with coal, a grate is necessary.

The Pipe--The pipe should extend 4 or 5 feet under the floor from the fire box, in order to have all the intense heat taken from the smoke and so remove all danger of fire.

Floor--Make the floor of concrete, though wooden floors have been used by cutting out the floor a few feet above the fire box and filling the space with sand and gravel.

The Hover--The hover may be made of any material, preferably metal. The main thing is to have the hover about 10" from the floor and allow 7 square inches per chick and twice that amount of space per poult. Do not expect the chick to sleep under the hover. Rather they will sleep in the space receiving the reflected heat as with any other hover.

FORAGE FROM IMPROVED PASTURES

Livestock are wasteful in their grazing habits. Instinctively, they search out the most palatable plants and plant parts--literally the cream of the pasture crop--and are inclined to avoid less palatable forage.

Recognizing this, farmers and scientists have searched for ways to encourage livestock to eat more of the forage that is available to them from pastures, thus cutting down on waste and increasing the efficiency of forage use. One way this has been done is through use of various systems that help control the availability of forage to livestock.

Three forage utilization systems that have evolved in recent years are rotation grazing, strip grazing, and green feeding. These systems can be used not only to encourage forage consumption by livestock, but also to protect plants from overgrazing and other damage.

The systems provide patterns for grazing and harvesting forage that are designed for efficient and practical management of improved grasslands. Their successful operation depends on skillful judgment that is based in turn, on an intimate knowledge of both plants and livestock.

Highly important to the success of the systems is the ability of farmers to recognize signs of inefficient forage use and to correct conditions that bring them about. These signs show up in either plants or livestock, or both. They can be avoided if grazing or harvesting is started and ended at the correct time and stage of plant growth, if the proper numbers and kinds of livestock are grazed on an area, and if plants are provided sufficient opportunity to recover before grazing or harvesting is repeated.

Skill in making these management decisions is actually the key to efficient use of pastures. With good management, it is possible to use forage efficiently with any of the utilization systems. Rotation grazing, strip grazing, and green feeding provide ways for reinforcing managerial skill with such features as planned plant rest periods and a high degree of control over grazing and harvest.

No single system of forage utilization fits all farming situations. Each farm has its own set of requirements and such factors as animal and seasonal needs for forage should be carefully considered before selecting a system.

Increasing Livestock Production with Forage

There may be a number of ways that livestock production can be increased with forage on a particular farm. These include: (1) Increasing the forage potential of a pasture through use of more productive plants and better cultural methods and by intelligent use of different plant species that mature at different times during the season; (2) decreasing waste of forage during grazing, harvesting, and feeding; (3) decreasing damage to plants from trampling or overuse; and (4) by combining two or more of these possible changes.

Pasture with a high forage yield potential is the starting point for high animal production per acre. Efforts to improve production through grazing management may be fruitless if pastures are poor. Skillful management becomes increasingly important as pastures are made more productive, because the possibilities of wasteful use and damage to plants are also increased. Dense, fast-growing plants are particularly vulnerable to damage from trampling and overgrazing.

DEVELOPMENT OF MODERN FORAGE UTILIZATION SYSTEMS

Modern systems for utilizing forage resulted from research and practical experience. Dating from 1930, scientists and farmers made some of the most significant contributions toward improving pastures and their use. Refinements were made in pasture fertilization, irrigation, and other cultural practices. Plant breeders developed better pasture plants. As these were released to growers, more and more land was seeded to adapted, highly productive grasses and legumes. Annual, biennial, and semi-permanent pastures gained places of prominence alongside permanent pastures.

Interest also centered on improving methods of grazing and harvesting pasture forage. Dairy farmers, in particular, attempted to find better ways to utilize forage, extend grazing periods, and obtain more uniform levels of milk production. Some of them experimented with a grazing method developed in Germany called the Hohenheim system.

Designed especially for dairy cattle, it involved heavy fertilization. Pastures were divided into smaller grazing areas and cattle were permitted to graze the areas in rotation.

The Hohenheim system was the forerunner of modern rotation grazing. The rotation system was first used with bluegrass and other low-growing plants in permanent pastures. Later, it was found to fill an important requirement in grazing improved pastures containing erect, highly productive new species of grasses and legumes. Unlike low-growing plants, these new species proved to be especially sensitive to overgrazing and continuous grazing. The rotation system provided a way to control grazing so that the highly productive plants could be protected.

Strip grazing is a variation on rotation grazing that has been used in New Zealand and Australia for over two decades and for a shorter period in the United States. With this system, livestock are moved onto a new strip of pasture each day.

Green feeding is a modern version of a system of cutting and hand feeding fresh forage that was first used in this country more than 150 years ago. With the present system, livestock never enter the pasture, but forage is harvested by machine and brought to them.

ROTATION GRAZING

The rotation grazing system provides a way to utilize forage by confining livestock to an area so small that they will eat all pasture plants to a desired height in a given period of time. When grazing is completed on an area, plants are allowed to establish new growth before being grazed again. These rest periods help prevent destruction of highly productive grasses and legumes.

Maintenance of desirable pasture plants as well as more efficient utilization of forage are the two major factors that contribute to the efficiency of rotation grazing. The individual contribution of these two factors is usually difficult to determine.

Rotation grazing helps to reduce damage to forage from trampling, which can cause great waste in dense, tall crops if grazing is poorly managed. Cattle in rotationally grazed pastures usually obtain the forage they require in less time than cattle on pastures grazed continuously and therefore conserve energy for meat and milk production.

Because pastures are alternately grazed and left idle during rotation grazing, such jobs as fertilization, clipping for weed control, and irrigation can be done on areas not in use without the interference of grazing livestock. For the same reason, excess forage can easily be harvested for hay or silage, thereby, in effect, temporarily reducing the area required for grazing. This permits considerable flexibility in the number of animals that can be grazed on an area during the season.

From the standpoint of management, rotation grazing is relatively simple to use. A pasture is divided into several grazing areas with electric fence. The number of grazing areas, size of the areas, and livestock numbers are adjusted so that each area is grazed to a height that best maintains the seeded species, and the time for plant rest periods is geared to the growth rate of the pasture?

Plant growth rate varies during the season, a factor that will regulate both the number of grazing livestock and the size of the grazing areas. During the period of flush plant growth in the spring, for example, it may be impossible to move animals through all pasture areas and adequately graze each area. Surplus forage may be harvested for hay or silage. Later, as the rate of plant growth slows down, animals may graze through all areas at a relatively rapid pace.

Livestock are usually turned onto the first area as soon as they can get a "good bite", or at the earliest time compatible with the animals' obtaining a reasonable amount of forage, yet not damaging desirable plant species.

During the first round of grazing in the spring, livestock are permitted to progress through the pasture areas, grazing forage down to the recommended height, until the area on which grazing was first begun has recovered sufficiently to be grazed again. The animals are then moved back to this area and the areas untouched during the first round of grazing are cut for hay or silage.

Milk production may fluctuate during the period dairy cows are grazing an area of pasture under the rotation system. Production may be at a high level for a few days after the animals are turned onto an area, then slacken after the more nutritious plants are eaten, usually reaching its lowest point just before the cows are moved to a new area. This cyclic pattern of production usually does not lower total seasonal milk production.

A variation on conventional rotation grazing, called the split-herd system, is sometimes used with dairy cattle. The herd is divided into low and high producers, and cattle are rotated through grazing areas so that high producers are first to be turned onto a new area. They remain on the area for a short period of time, usually a week or less, then are moved to another new area. The low producers then are moved onto the pasture area partially grazed by the high producers.

The split-herd system gives high-producing cattle the advantage of being first to graze nutritious new pasture growth. Theoretically, the quality of forage they consume is consistently high. ARS studies indicate that some increase in milk production may be expected from this system, compared with conventional rotation grazing, provided that sufficiently large differences in milk-producing capabilities exist between the high- and low-producing groups of cows.

STRIP GRAZING

Strip grazing is a method of intensified rotation grazing that provides smaller grazing areas and shorter grazing periods. Livestock are moved onto new forage each day, helping to lessen the chance of fluctuations in animal production such as those sometimes experienced with conventional rotation grazing.

There appears to be no convincing evidence that strip grazing will result in appreciably greater animal production or more cow-days of grazing per acre than a well-managed rotation grazing system. In comparisons of strip and rotation grazing in which the number of animal units permitted to graze an area were kept equal, total seasonal animal production from pastures under the two systems was identical.

Strip grazing is more complicated than rotation grazing because of the chore of moving livestock to a fresh strip of pasture each day. Most farmers use a single strand of electric fence that can be readily shifted from strip to strip.

Bloat is less likely to occur during strip grazing than during continuous or rotation grazing because the more limited grazing area encourages cattle to eat coarse, more mature forage along with the bloat-causing immature, leafy portions of legumes.

When dairy cattle are strip grazed on pastures at the Agricultural Research Center, Beltsville, Md., the width of pasture strips is adjusted each day so that forage is well utilized. This involves daily observation of both livestock and pasture to determine if the animals are receiving adequate forage and if there is damage to the pasture stand. As the cattle progress through the pasture, forage on ungrazed areas that obviously will not be needed for grazing is harvested for hay or silage.

Clipping of pasture areas is recommended. This practice helps control weeds, removes clumps of uneaten forage, and promotes young and nutritious forage growth. Hay and silage may be made from any pasture area if excellent growing conditions cause a surplus of plant growth for grazing.

GREEN FEEDING

The green feeding system is also called soiling, green chop, mechanical grazing, zero pasture, and zero grazing. As some of these terms indicate, pasture forage is harvested with machinery, rather than livestock. This way, energy normally used by livestock for grazing is used in meat and milk production.

Green feeding is an adaptation of a method of cutting and feeding forage crops first used in this country in the early 1900's to supplement pastures. The early system never became generally popular because it was complex, involved much hand labor, and the growing of a succession of crops throughout the season.

Interest in feeding fresh cut forage revived with the development of high-yielding forage crops and such labor-saving machinery as field forage choppers and self-unloading wagons.

Equipment and labor requirements are still relatively high with the modern system of green feeding because forage is cut, chopped, and fed once or twice daily. On the other hand, the need for fencing, watering facilities, shade, and other requirements associated with grazing is reduced or eliminated.

A dairy herd of at least 35 to 40 cows is required to make green feeding economical.

The principal advantage of green feeding is the possibility of meeting forage needs with fewer acres than would be required with grazing. The system helps avoid waste caused by selective grazing, trampling, or fouling with droppings for two reasons: (1) livestock never enter the fields, and (2) both leaves and stems of plants are harvested and fed.

The prospect of reducing acreage requirements for forage is especially attractive on farms where operating costs are high, labor is plentiful, and where land for pasture is scarce. However, green feeding of improved pasture forage has seldom resulted in more animal products per acre than well-managed rotation grazing when animals have been allowed equal time to utilize the crop. Production per animal has also been about equal in such comparisons.

In some cases, the success reported with green feeding has resulted from not only changing the forage utilization system, but also from changing from low-yielding to high-yielding forage crops. Studies in which ladino clover—orchardgrass forage was utilized either by rotation grazing, strip grazing, or green feeding, showed no advantage in animal production that favored green feeding over the other systems.

A high degree of crop management skill is necessary for successful operation of green feeding. Excellent management is required to produce a continuous succession of crops and to harvest them and feed them during their most nutritious stage of growth.

Generally, green feeding involves more risks than a grazing system. Machinery breakdowns and rainy weather can slow down or prevent daily harvest. Some risks can be offset by providing emergency pasture near feedlots or by having an emergency supply of hay or silage. Other factors related to green feeding, but not to grazing systems, include hauling of manure from feedlots, the need for surfaced feedlots, and sanitation and disease problems that may occur as a result of confining livestock to drylot.

THE ROLE OF MANAGEMENT IN FORAGE UTILIZATION

Determination of the best way to improve livestock production through better use of forage is a complicated process because two biological systems are involved; livestock and the pasture plants. Every decision about one in some way affects the other. Understanding certain basic interrelationships that exist between plants and livestock is important in making forage management decisions. The better these interrelationships are understood, the greater are the possibilities of making effective decisions.

The forage utilization system selected for a farm should result in maximum net dollar returns from pasture and livestock. To accomplish this, it would appear that the ideal system should provide the highest possible animal production by the use of all forage that grows in a pasture. In practice, however, top animal production is possible when livestock consume only the most nutritious plants in the pasture and avoid coarse, more mature plants. This is the pattern of wasteful selective grazing cattle instinctively follow if not controlled. When livestock are compelled to eat all plants in the pasture, the overall nutritive value of the forage they consume is lowered by the mature forage plants and weeds it contains. The result is less-than-maximum animal production.

In the interest of efficiency, it is good management to compromise between obtaining maximum animal production and the using of all forage in a pasture. This compromise is accomplished through management decisions that avoid excessive waste of forage and damage to the pasture from overuse without sacrificing animal production unnecessarily to favor pasture growth. They result in a pasture utilization plan that takes into account the fact that various ages and classes of livestock have different forage requirements and the fact that ample forage should be available throughout the season, including critical production periods.

Decisions About Intensity of Pasture Use

Successful forage management decisions effect a satisfactory balance between the capacity of a pasture to produce quality forage and the capacity of livestock to produce meat or milk. This balance is mutually beneficial to the plants and livestock. In the final analysis, such management decisions involve the determination of a correct stocking rate for grazing (animal days of grazing per acre) or a correct rate of harvest for green feeding.

Accurate rates for stocking or for harvesting take into account individual animal differences. This requires an intimate knowledge of the productive capacities of the animals.

Livestock differ in their inherited capacities to produce meat and milk. Some animals may eat more forage than they can possibly convert into animal products. Others may make efficient use of a relatively high intake of forage, supplemented with concentrates, because of their inherited high capacity for production.

There also are seasonal variations in the productive capacities of pastures. A special problem occurs during the period of flush plant growth in the spring, when livestock usually cannot eat all of the forage that is available. This problem may be solved by reducing the size of the pasture area grazed and by harvesting excess forage for silage or hay, or by increasing the number of livestock grazing the pasture.

Signs of Inefficient Pasture Use

Signs of inefficient pasture use are most likely to develop when livestock are permitted to graze a pasture continuously with a minimum of control. The animals are free to follow their natural tendencies to select only palatable, tender leaves and plants and to avoid more mature and less palatable plants.

The signs are characterized by areas of over-mature forage, areas of extremely short forage that has been frequently and closely grazed, and changes in the pasture stand from more productive to less productive species and weeds.

Close observation of both pasture and livestock can result in early detection of the signs of inefficient pasture use. Rotational and strip grazing generally result in closer management than continuous grazing. Condition of both pasture and livestock may be observed regularly as animals are moved from area to area. Danger signs may be noted and adjustments made in the size of grazing area or the length of grazing period.

Green feeding provides an opportunity for close regulation of the use of pasture forage, since it makes possible strict control over the entire operation. Harvest may be done in a manner that prevents plant damage and waste. In addition, daily contact with livestock permits adjustments in the amount of forage fed to achieve a desired level of animal production.

Rest Periods for Plant Recovery

The rest periods for plant recovery that are an integral part of rotation and strip grazing and green feeding help bring about a balance between production and consumption of forage. Used correctly, they protect pastures from overuse and help assure that enough nutritious forage will be available to livestock throughout the pasture season.

Managing forage in such a way as to include adequate rest periods has become an important feature of the three pasture systems because the plants predominant in improved pastures are especially sensitive to close, continuous grazing or frequent harvesting. These plants are more erect and more productive than the low-growing plants in permanent pastures and include such legumes and grasses as ladino clover, alfalfa, the fescues, Coastal bermudagrass, dallisgrass, orchardgrass, bromegrass, and timothy.

Because of their height, a larger amount of the leaf surface of plants in improved pastures may be easily eaten or trampled by livestock. Loss of leaf surface is a setback to plants. Leaves that are removed ordinarily would be used to manufacture carbohydrates for continued growth and reserves stored in roots. When defoliated, plants rely on root reserves, and continuous defoliation results in depletion of these reserves and death of the plants. If grazed too frequently and too close, the improved plants may be forced out of the pasture stand, often to be replaced by weeds.

During rest periods, forage plants produce new foliage from shoots near the ground. This foliage is highly digestible and high in protein content. When regular rest periods are provided, the plants will continually produce new shoots and the foliage remains young and nutritious. New foliage has a very high vitamin A value because it is rich in carotene. It is also rich in B-complex vitamins, vitamin E, ascorbic acid, and certain other essential vitamins. Calcium and phosphorus contents also are higher than in mature forage.

Livestock generally prefer young plants, or the young and actively growing leaves and stems of plants. In their search for these, they will pass by more mature plants. This selective grazing may be a special problem when grazing is continuous and poorly controlled. On the other hand, the greater degree of control of forage use provided by rotation grazing, strip grazing, and green feeding minimizes the problem by compelling livestock to eat all plants and plant parts.

Production of high-producing animals may suffer, however, if they are compelled to eat low quality forage.

The Importance of Timing

Management involves determining when grazing should be started, how long it should be continued on each pasture area, and when and how often forage should be harvested for green feeding.

The maturity, leafiness, and yield of forage at the time it is grazed or harvested are important in determining the feeding value of any pasture crop. Best yields of nutritious forage are obtained when plants are young, vegetative, and actively growing. In this stage, the plants are more palatable, more nutritious, and more digestible than when they are mature.

Grazing should be started in the spring as soon as livestock can obtain an adequate amount of forage, yet not damage the plant stand. Rotation grazing may be continued on each pasture area until such mixtures as bromegrass and alfalfa are grazed to a minimum average height of 3 to 4 inches, and mixtures such as orchardgrass and clover are grazed to an average height of 2 inches. During hot, dry weather, however, these minimum heights should be raised an inch or more. The size of strip-grazed pasture areas should be so adjusted that the forage is grazed to the minimum height desirable for the plants at the end of a 24-hour period.

The sequence for chopping for green feeding should be so timed that forage is cut when nutritious and adequate recovery periods are provided between harvests. Cutting for green feeding generally should be started when plants are in the early hay stage, which occurs a week or more after the plants are ready for grazing.

FITTING THE FORAGE UTILIZATION SYSTEM TO THE FARMING SITUATION

Properly managed, each of these three improved forage utilization systems can advance the efficiency of livestock production. But which of the three systems will best meet farmers' needs, can only be determined by evaluating their relative merits and drawbacks in terms of individual farming situations.

VETERINARY MEDICINE

IMMUNOLOGICAL PRODUCTS

What They Are and How They Work

"Immunity" means, in general terms, a resistance to infectious disease. Textbooks on the subject mention several types or classes of immunity, two of which are especially important from the standpoint of disease control in domestic animals and poultry. An understanding of these two types of immunity is essential if one is to obtain maximum benefits from the use of biological products.

The injection of a Bacterin, Vaccine or Toxoid into an animal stimulates the animal's tissue cells to produce substances called antibodies which serve to protect the animal against infection by the particular organisms represented in the product. Since the cells of the treated animal are active in producing the antibodies, we speak of this as an *Active Immunity*. Active immunity developes gradually, requiring from one to four weeks to reach its maximum. This type of immunity lasts a relatively long time, although there is considerable variation, depending on the age and species of the animal, nature of the disease, quality of product used and other factors. For example, pigs actively immunized with Hog-Cholera Virus and Anti-Hog-Cholera Serum will, under ordinary conditions, remain resistant to Hog Cholera for life. On the other hand, dogs vaccinated with Rabies Vaccine gradually lose their immunity after about twelve months, which makes it necessary to revaccinate at least once each year.

The antibodies, which are present in the blood serum of an immunized animal, may be transferred to other animals by injections of this serum. Animals so treated acquire an immunity by virtue of the antibodies injected. This type of immunity is called *Passive Immunity* since the tissue cells of the treated animal are not involved in the production of the antibodies. Passive immunity is of short duration, lasting, on the average, about three to four weeks. Its effect, however, is immediate, and for this reason immune serums or antiserums are of great value in the treatment of affected animals and also in providing immediate protection to animals that have been or are likely to be exposed to disease soon.

There are many factors which affect the degree and duration of active immunity. It is generally recognized that very young animals do not immunize as readily as older animals. Nutritional deficiencies and other debilitating conditions may possibly interfere with the development of immunity, or even cause a decrease in the resistance of an animal that has been successfully immunized some time previously. In any large number of animals, one may occasionally encounter the rare individual which, for some unknown reason, is unable to develop an immunity, even when vaccinated with products that are highly effective in the vast majority of cases. Immunity, therefore, is a relative thing, dependent on many variable factors, including the individual.

BACTERINS

Bacterins are suspensions of bacteria which have been killed by heat or chemical means, thereby rendering them incapable of producing disease. The bacteria are first isolated from the blood or tissues of animals sick or dead of the disease. Their identity is established by exacting biological tests, and suitable culture media inoculated and incubated at blood temperature.

The culture medium is prepared with tissue juices and other ingredients to simulate the body conditions, and serves as the food for bacterial development. The bacteria, by this means, can be grown in large numbers, pure and free of all contamination.

After maximum growth has been reached, the cultures are removed from the incubator and a preservative added. The preservative acts also as the killing agent. Each culture is tested for sterility to determine definitely that all the organisms have been killed. Each batch of bacterin is subjected to microscopic examinations and animal inoculation tests to determine purity and safety of the product.

VACCINES

Vaccines constitute a group of biological products which, like bacterins, are employed for the purpose of producing an active immunity. They differ in many respects from bacterins and their composition is determined largely by the methods employed in growing the bacteria or viruses which comprise the active or immunizing agent in the product.

Bacterial Vaccines are suspensions of living bacteria which have been attenuated or weakened to such a degree that they are no longer capable of producing disease when injected into the animal body. Brucella Abortus Vaccine is a typical example of a bacterial vaccine.

Virus Vaccines are suspensions of ground tissues in which the virus has grown. Viruses will not grow and multiply in artificial culture media and consequently must be grown in or on the tissues of living animals. These tissues are collected at the proper time, ground, and processed in various ways to make the finished product. Certain vaccines, as for example Fowl Pox Vaccine, contain live virus since it is essential in this instance that the virus be alive in order to produce immunity. In Rabies and Encephalomyelitis Vaccines, however, the virus is killed by chemical agents. These viruses are capable of producing an immunity even though they are killed and, further, they could not be used safely if alive.

Hog-Cholera Virus, strictly speaking, is not a vaccine, and its virulence has not been interfered with. Its action is controlled in the body of the hog by the injection of Immune Serum which prevents the development of Hog Cholera. It is the virus which stimulates the development of an active, lasting immunity.

IMMUNE SERUMS

Practically all Immune Serums are prepared from animals which have previously been immunized by injecting into their bodies large and repeated doses of Bacterins. When sufficient immunity has been developed by this treatment, the animals are injected with large and repeated doses of living bacteria, the disease-producing powers or which have not been impaired in any way.

The blood of the animals is repeatedly tested, and when found to contain sufficient amounts of antibodies, the blood is collected, clarified, pasteurized, and preserved by the addition of a suitable preserving agent.

Immune Serums contain the antibodies specific for the disease germs used in immunizing the animal, and when injected into well animals in sufficient dosage, provide an immediate immunity against the specific disease.

The Immune Serum, when injected into an animal's body, does not stimulate that animal's body cells to produce antibodies. Therefore, the immunity conferred is transitory, lasting for relatively short periods of time.

Immune Serums are used to treat sick animals and to protect animals that have been or are likely to be exposed to infection. When injected into such animals in sufficient dosage, the antibodies immediately protect the tissues from further bacterial invasion.

The dosage generally recommended has been arrived at largely through experience. It has been found that large doses, in severe cases repeated in 4 to 8 hours (less severe cases, 12 to 24 hours), are much more effective than small doses repeated at more frequent intervals. Judgment as to the dosage to be employed in any given case would depend on the severity of the symptoms manifested, and the size of the animal.

CARE OF IMMUNOLOGICAL PRODUCTS

Bacterins, Vaccines, and Immune Serums are all adversely affected by exposure to heat and light. For this reason, they should always be stored under refrigeration, preferably at 35 to 45° F., but should not be frozen. All biological products are marketed in sealed pasteboard boxes in order to protect the product from light. Live Viruses and Bacterial Vaccines are much more sensitive to the effects of heat than are Bacterins and Immune Serums; therefore, particular care should be taken to keep such products cold until ready for use.

SANITATION

This term, while familiar to everyone, has been more or less misunderstood, abused and misused until the public generally has lost sight of its real meaning, value, and importance.

Sanitation means to render wholesome or healthful, and requires the use of methods which have proved to be effective in the prevention of disease and the promotion of health.

The term, cleanliness, means the removal of all filth and dirt, freedom from whatever is foul and offensive (rubbish, animal body discharges, etc.).

Therefore, the first essential of sanitation is cleanliness. Second, disinfection.

Sanitation should be maintained at all times.

Disinfection means destroying disease-producing bacteria in and about the premises, and making conditions unfavorable for their development. Disinfection is accomplished by the use of dips, disinfectants, etc.

The effectiveness of dips and disinfectants is dependent upon cleanliness. Before disinfecting, it is necessary first to clean thoroughly and remove all dirt, rubbish, etc., in order to be sure that the disinfecting agent will come in direct contact with and destroy any disease bacteria which may be present.

Thorough cleaning and disinfection do not, in themselves, constitute sanitation. It is of equal importance to clean and disinfect the premises at periodic intervals to maintain sanitation.

Sanitation plays a most important part in the prevention of diseases by reducing the number of disease bacteria on the premises with which animals will come in contact.

It is especially important that strict sanitary measures be employed on premises where infectious contagious diseases are present. Sanitation plays an important part in preventing the spread of any infectious disease. It should be remembered that the number of disease bacteria taken within an animal's body determines whether or not the animal will contract the disease and, if so, whether or not the disease will be mild or severe.

Through cleanliness and disinfection, the number of disease bacteria is greatly decreased, and healthy animals are less apt to take within their bodies a sufficient number of the bacteria to produce disease.

DISINFECTING AGENTS

Effective disinfection depends on four things: First, the phenol coefficient of the disinfectant. Second, the dilution at which the disinfectant is used. Third, proper cleaning before application. And Fourth, thoroughness of application.

The phenol coefficient indicates the killing strength of a disinfectant as compared to phenol (carbolic acid).

Disinfectants are diluted with water for use, and the extent of dilution will depend largely on the phenol coefficient. As a general rule, disinfectants should be diluted not more than 20 times the phenol coefficient. For example, a disinfectant with phenol coefficient 5 may be diluted 100 times (20 x 5); that is, one part disinfectant to 99 parts water. In many instances stronger solutions are preferred. Obviously a disinfectant of high phenol coefficient will go farther than one of low coefficient. It is seldom economical to use disinfectants of less than coefficient 5.

Cleaning before disinfection is essential if the disinfectant is to do an effective job. Excessive amounts of dirt, filth, and organic matter interfere with the action of disinfectants.

Thorough application means applying the disinfectant to all contaminated surfaces and objects, with special attention to corners, cracks, crevices, and other points that might easily be overlooked.

The use of coal tar disinfectants, such as Dip, for general farm disinfection and many other purposes is well known. In certain operations, such as dairying, coal tar disinfectants are unsuitable because of their pronounced coal tar odor.

Pine Disinfectant is an aromatic, disinfectant and deodorant concentrate with a refreshing pine odor. The pine oil is emulsified in such a manner that it retains its several valuable properties and mixes readily with water. Pine Disinfectant is especially recommended for farm, office, household, and kennel use.

Odorless Disinfectant and Poultry Disinfectant, containing quaternary ammonium compounds, are among the most recent developments in the sanitation field. These products have a high phenol coefficient, are odorless, tasteless, non-toxic, non-irritating, and non-corrosive. They are especially suited to all dairy and poultry sanitation needs. In suitable concentrations, they are effective deodorants as well as disinfectants. Poultry Disinfectant, in proper strength, will kill the virus of Newcastle disease in contaminated brooder houses, batteries, and other equipment, and in addition, may be used as a sanitizing agent in the drinking water.

APPROXIMATE MEASURES

1/2 ounce (fluid)	4 teaspoonfuls (tsp.)
1/2 ounce (fluid)	1 tablespoonful
4 ounces (fluid)	1 teacupful
8 ounces (fluid)	1 glassful
1 c.c.	16 drops
4 c.c.	1 teaspoonful
15 c.c.	1 tablespoonful

USE AND CARE OF SYRINGES

All syringes and needles should be thoroughly cleaned and sterilized by boiling for at least 15 minutes just before using. Syringes and needles that have been cleaned thoroughly may be sterilized by immersing in a suitable disinfectant solution for 30 minutes.

To adjust syringe, push plunger all the way in and turn palm rest or handle to the right. If too tight, turn to the left. Place dosage nut or set screw on plunger stem in accordance with dose to be administered.

METHOD OF FILLING SYRINGE

Shake bottle well before drawing the contents of the bottle into the syringe. Force a needle through the diaphragm of the rubber stopper. Injection of a little air into the bottle between withdrawals will prevent the formation of a partial vacuum. Draw the product into the syringe direct from the bottle.

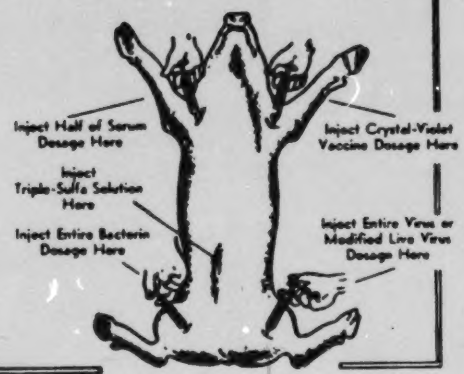
Attach another sterile needle to the syringe to inject the product.

Biological products should be used the same day the stopper is punctured. When vaccinating, protect this class of products from direct sunlight and intense heat to avoid impairment of immunizing properties.

After using syringes, they should be taken apart, thoroughly

SWINE INJECTION DIAGRAM

Average farm conditions seldom justify the use of a minimum dose of Anti-Hog Cholera Serum. It is safer to use a larger dose of serum. Recommended doses for field vaccination: Anti-Hog Cholera Serum: 25% to 50% above the minimum dosage. Hog Cholera Virus: 3 to 5 cc. regardless of age or weight.

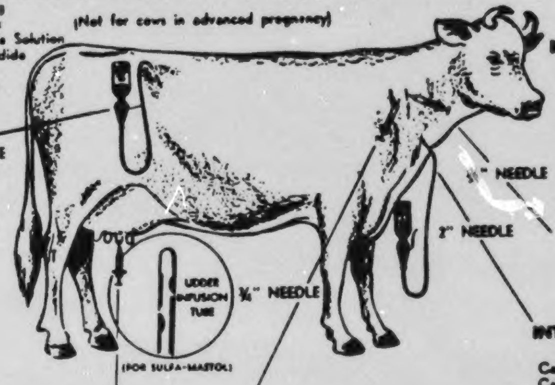

Inject Half of Serum Dosage Here
Inject Triple-Sulfa Solution Here
Inject Entire Bacterin Dosage Here
Inject Crystal-Violet Vaccine Dosage Here
Inject Entire Virus or Modified Live Virus Dosage Here

CATTLE INJECTION DIAGRAM

INTRAPERITONEAL INJECTION—RIGHT SIDE ONLY

Cal-D-Mag
Cal-O-Dex
Triple-Sulfa Solution
Sodium Iodide Solution
Thio-Nitro Solution

(Not for cows in advanced pregnancy)


2" NEEDLE
UDDER INFUSION TUBE
(FOR SULFA-MASTOL)
¾" NEEDLE
½" NEEDLE
2" NEEDLE

INTRAMUSCULAR INJECTION—DEEP INTO THE MUSCLE

Mixed Bacterins
Hemorrhagic-Septicemia Bacterin
Corynebacterium-Pasteurella Bacterin (Whole Culture)
Blackleg Bacterin Whole Culture
Anti-Hemorrhagic-Septicemia Serum
Camphoil
Sterile Glucose Solution
Sodium Cacodylate Solution
Glo-Bestrol
Penicillin

INTRAVENOUS INJECTION—JUGULAR VEIN

Cal-D-Mag
Cal-O-Dex
Sterile Glucose Solution
Anti-Hemorrhagic-Septicemia Serum
Anti-Corynebacterium-Pasteurella Serum
Sodium Cacodylate Solution
Triple-Sulfa Solution
Sodium Iodide Solution
Thio-Nitro Solution

UDDER INFUSION

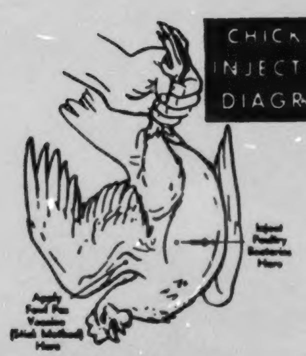
Super-Mastol
Mastitis Treatment
Sulfa-Mastol

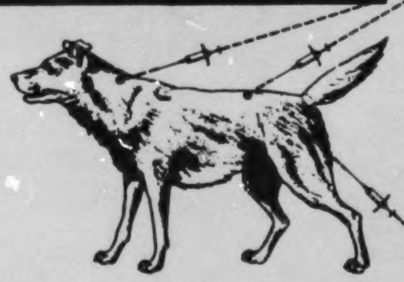
SUBCUTANEOUS INJECTION—UNDER THE SKIN

Blackleg Bacterin Whole Culture (Alum Treated)
Brucella Abortus Vaccine — Calves only (4 to 8 months)
Anti-Hemorrhagic-Septicemia Serum
Chauvei-Septicus-Pasteurella (Triple Bacterin)

GLOBE LABORATORIES

CHICKEN INJECTION DIAGRAM


Inject Poultry Bacterins Here
Apply Fowl Pox Vaccine (Stick Method) Here



SUBCUTANEOUS INJECTION

UNDER THE SKIN

- Canine Distemper Vaccine
- Rabies Vaccine
- Mixed Bacterin (Canine) Formula 1
- Sterile Glucose

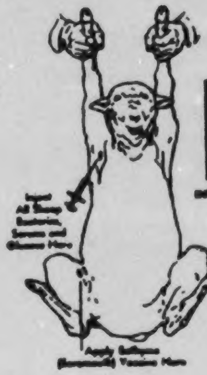
INTRAMUSCULAR INJECTION

DEEP INTO THE MUSCLE

- Camphoil
- Penicillin or other antibiotics.

GLOBE LABORATORIES

SHEEP INJECTION DIAGRAM


Inject All Sheep Bacterins, Serums and Glucose Here
Apply Soremouth (Ecthyma) Vaccine Here

INTRAPERITONEAL INJECTION

(Same as in Cattle)

(Not for ewes in advanced pregnancy)

Triple-Sulfa Solution
Cal-D-Mag
Cal-O-Dex
Thio-Nitro Solution

See "Instructions For Making Various Types Of Injections In Domestic Animals."

BEST COPY AVAILABLE

cleaned and dried, and placed in a dark cool place until again needed.

SITE OF INJECTION

The best place to inject most bacterins, vaccines, etc., in horses and cattle is in the side of the neck, midway between the head and shoulders; sheep and swine, under the foreleg (armpit). See Center Spread.

Needles after each injection should be rinsed in a disinfectant solution but care should be exercised to insure that the disinfectant solution is expelled from the lumen of the needle before use.

INSTRUCTIONS FOR MAKING VARIOUS TYPES OF INJECTIONS IN DOMESTIC ANIMALS

Before making an injection, read the bottle label carefully to determine indications, cautions, proper dosage, frequency of administration, and recommended method of administration. Then consult these directions for detailed instructions on how to make the type of injection recommended on the bottle label.

INTRAVENOUS: Injection directly into the veins. This method is generally used when rapid and effective action is needed to save life.

DIRECTIONS FOR MAKING AN INTRAVENOUS INJECTION IN CATTLE

Equipment Needed:

1. Choke rope--a rope or cord about 5 feet long, with a loop in one end, to be used as a tourniquet.
2. Gravity flow intravenous set. (See Fig. 1)
3. Hypodermic needles, 16 gauge, 1½ to 2 inches long and very sharp. Use new needles. Dull needles will not work. Extra needles should be available in case the one being used becomes clogged.

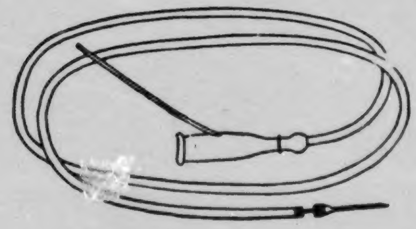


FIGURE I

4. Scissors or clippers.

5. 70% rubbing alcohol compound or other equally effective antiseptic for disinfecting the skin. Blue Lotion is ideal for this purpose.

6. The medication to be given.

Preparation of Equipment:

Thoroughly clean the needles and intravenous set and disinfect them by boiling in water for twenty minutes.

Warm the bottle of medication to approximately body temperature and keep warm until used.

Preparation of the Animal for Injection:

1. Approximate location of vein. The jugular vein runs in the jugular groove on each side of the neck from the angle of the jaw to just above the brisket and slightly above and to the side of the windpipe. (See Fig. II and III.)

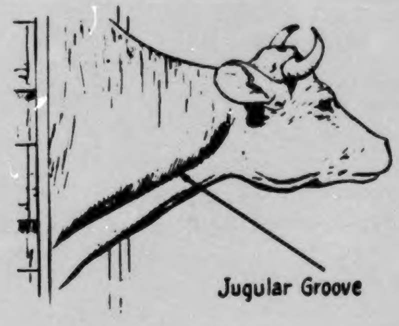


FIGURE II

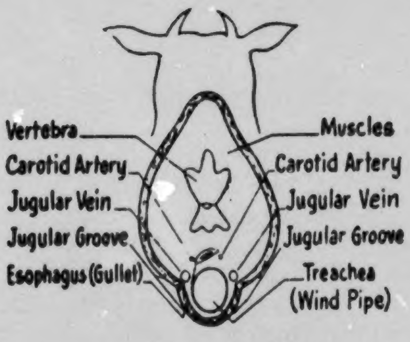

Vertebra
Carotid Artery
Jugular Vein
Jugular Groove
Esophagus (Gullet)
Muscles
Carotid Artery
Jugular Vein
Jugular Groove
Treachea
(Wind Pipe)

FIGURE III

2. Restraint--a stanchion or chute is ideal for restraining the animal. With a halter, rope, or cattle leader (nose tongs), pull the animal's head around the side of the stanchion, cattle chute or post in such a manner to form a bow in the neck (See Fig. IV), then snub the head securely to prevent movement. By forming the bow in the neck, the outside curvature of the bow tends to expose the jugular vein and make it easily accessible. Caution. Avoid a tight rope or halter around the throat or upper neck which might impede blood flow. Animals that are down present no problem so far as restraint is concerned.

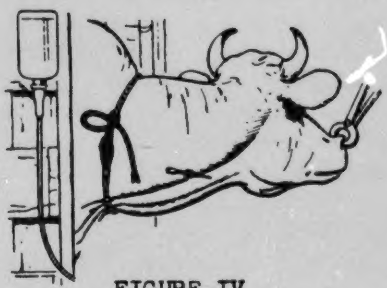


FIGURE IV

3. Clip hair in area where injection is to be made (over the vein in the upper third of the neck). Clean and disinfect the skin with alcohol or other suitable antiseptic.

Entering the Vein and Making the Injection:

1. Raise the vein; this is accomplished by tying the choke rope tight around the neck, close to the shoulder. The rope should be tied in such a way that it will not come loose and so that it can be untied quickly by pulling the loose end (See Fig. IV). In thick-necked animals, a block of wood placed in the jugular groove between the rope and the hide will help considerably in applying the desired pressure at the right point. The vein is a soft flexible tube through which blood flows back to the heart. Under ordinary conditions it cannot be seen or felt with the fingers. When the flow of blood is blocked at the base of the neck by the choke rope, the vein becomes enlarged and rigid because of the back pressure. If the choke rope is sufficiently tight, the vein stands out and can be easily seen and felt in thin-necked animals. As a further check in identifying the vein, tap it with the fingers in front of the choke rope. Pulsations that can be seen or felt with the fingers in front of the point being tapped will confirm the fact that the vein is properly distended. It is impossible to put the needle into the vein unless it is distended. Experienced operators are able to raise the vein simply by hand pressure, but the use of a choke rope is more certain.

2. Inserting the needle. This involves three distinct steps. First, insert the needle through the hide. Second, insert the needle into the vein. This may require two or three attempts before the vein is entered. The vein has a tendency to roll away from the point of the needle, especially if the needle is not sharp. The vein can be steadied with the thumb and finger of one hand. With the other hand, the needle point is placed directly over the vein, slanting it so that its direction is along the length of the vein, either toward the head or toward the heart. Properly positioned this way, a quick thrust of the needle will be followed by a spurt of blood through the needle, which indicates that the vein has been entered. Third, once in the vein, the needle should be inserted along the length of the vein all the way to the hub, exercising caution to see that the needle does not penetrate the opposite side of the vein. Continuous steady flow of blood through the needle indicates that the needle is still in the vein. If blood does not flow continuously, the needle is out of the vein (or clogged) and another attempt must be made. If difficulty is encountered, it may be advisable to use the vein on the other side of the neck.

3. While the needle is being placed in proper position in the

vein, an assistant should get the medication ready so that the injection can be started without delay after the vein has been entered. Remove the rubber stopper from the bottle of intravenous solution, connect the intravenous tube to the neck of the bottle, invert the bottle and allow some of the solution to run through the tube to eliminate all air bubbles.

4. Making the injection. With needle in proper position as indicated by continuous flow of blood, release the choke rope by a quick pull on the free end. This is essential--the medication cannot flow into the vein while the vein is blocked. Immediately connect the intravenous tube to the needle, and raise the bottle. The solution will flow in by gravity (See Fig. V.). The rate of flow can be controlled by pinching the tube between the thumb and forefinger or by raising and lowering the bottle. Bubbles entering the bottle through the air tube or valve indicate the rate at which the medication is flowing. If the flow should stop, this means the needle has slipped out of the vein (or is clogged) and the operation will have to be repeated. Watch for any swelling under the skin near the needle, which would indicate that the medication is not going into the vein. Should this occur, it is best to try the vein on the opposite side of the neck. Sudden movement of the animal, especially twisting of the neck or raising or lowering the head, may sometimes cause the needle to slip out of the vein. To prevent this, tape the needle hub to the skin of the neck to hold the needle in position. Whenever there is any doubt as to the position of the needle, this should be checked in the following manner: Pinch off the intravenous tube to stop flow, disconnect the tube from the needle and re-apply pressure to the vein. Free flow of blood through the needle indicates that it is in proper position and the injection can then be continued.

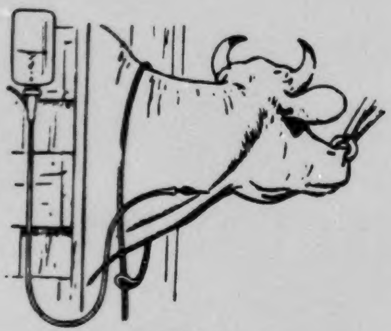


FIGURE V

5. Removing the needle. When injection is complete, remove needle with a straight pull. Then apply pressure over area of injection momentarily to control any bleeding through needle puncture, using cotton soaked in alcohol or other suitable antiseptic.

Precautions:

1. Inexperienced persons will find the intraperitoneal method simpler than the intravenous method and, except in cases of extreme emergencies, intraperitoneal injection is the method of preference, provided this method is recommended on the label of the product being used.

2. To reduce the likelihood of shock, intravenous solutions should be warmed to approximately body temperature before injection.

3. Rapid injection may occasionally produce shock. Administer slowly. Rate of injection may be controlled by raising or lowering the bottle or pinching the tube. The animal should be observed at all times during the injection in order not to give the solution too fast. This may be determined by watching the respiration of the animal and feeling or listening to the heart beat. If the heart beat and respiration increase markedly, the rate of injection should be immediately stopped by pinching the tube until the animal recovers approximately to its previous respiration or heart beat rate, when the injection can be resumed at a slower rate.

4. If symptoms of shock are seen or the animal shows any signs of distress, administration can be interrupted by pinching the intravenous tube. If symptoms persist, the injection should be terminated entirely.

INTRAPERITONEAL: Injection is made through the abdominal wall and directly into the abdominal cavity. This method is used when a large quantity of solution is to be given, rapid absorption is desired, and the vein cannot be used.

DIRECTIONS FOR MAKING AN INTRAPERITONEAL INJECTION IN CATTLE

Equipment Needed:

1. Gravity flow intravenous set.

2. Hypodermic needles, 14 or 16 gauge, 1½ or 2 inches long and very sharp. Extra needles should be available in case the one being used becomes clogged.

3. Scissors or clippers.

4. 70% Rubbing Alcohol Compound or other equally effective antiseptic for disinfecting the skin. Blue Lotion is ideal for this purpose.

5. The medication to be given.

Preparation of Equipment:

Thoroughly clean the needles and intravenous set and disinfect them by boiling in water for twenty minutes. Warm the bottle of medication to approximately body temperature and keep warm until used.

Locating the Injection Area:

An intraperitoneal injection is made through the belly wall on the animal's right side (never on the left) at a point about three inches below the edge of the loin muscles and midway between the point of the hip and the last rib. This is the center of a triangular depression called the "hollow of the flank," illustrated in Figure VI.

Preparation of the Animal for Injection:

The injection can be made most easily if the animal is restrained

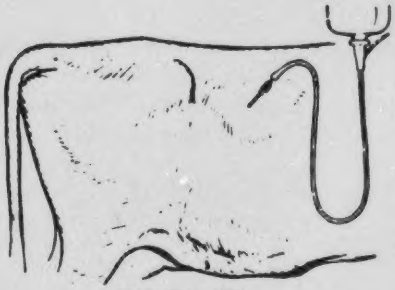


FIGURE VI

in a standing position, preferably in a stanchion or cattle chute. Clip the hair from the area where the needle is to be inserted. Then swab the area vigorously with alcohol or other equally effective antiseptic to clean and disinfect the skin.

Inserting the Needle and Making the Injection:

At the center of the triangular depression, hold the needle perpendicular to the skin, thus pointing it approximately toward the center of the body. Then, with a quick thrust, insert the needle through the belly wall all the way to the hub. This will put the end of the needle into the peritoneal cavity. (In thick skinned animals where penetration is difficult, attach to the needle a sterile veterinary syringe with which the operator can obtain a better grip and make a more forceful thrust.)

When the needle is being placed in proper position, an assistant should get the medication ready by removing the rubber stopper from the bottle and attaching the intravenous tube to the neck of the bottle. Then invert the bottle and allow a small quantity of the solution to run through the tube to eliminate all air bubbles.

Connect the intravenous tube to the hub of the needle and elevate the bottle. If the needle is in proper position the solution will flow rapidly as indicated by a steady stream of bubbles entering the bottle through the air tube or valve. If the solution does not flow readily, disconnect the intravenous tube, withdraw the needle a short distance, and reinsert at the proper angle. If this fails to correct the trouble, the needle is probably clogged with a plug of tissue in which case a new needle should be used.

Removal of the Needle:

After the proper dosage has been administered, pinch off the tube to prevent further flow, disconnect the tube, and quickly withdraw the needle. Then swab the site of the needle puncture with alcohol or other equally effective antiseptics.

DIRECTIONS FOR MAKING AN INTRAPERITONEAL INJECTION IN SHEEP

First read the directions for making this injection in cattle. The principles involved are identical. Sheep can be easily restrained by an assistant who straddles the animal just in front of the shoulders. For sheep, use a 16-gauge needle, 1½ inches long.

Since the dosage for sheep is relatively small, an ordinary veterinary syringe of 25-cc or 50cc capacity is generally preferred instead of an intravenous set. Sterilize needles and syringes by boiling in water for 20 minutes. Disinfect the bottle stopper before puncturing. Use a separate needle for filling the syringe.

Make injection on the animal's right side as described under cattle. The triangular depression is not always apparent to the eye in heavily wooled animals, but after clipping the area the depression can be easily seen or felt with the hand. Be sure to disinfect the skin, as described under cattle, before making the injection.

DIRECTIONS FOR MAKING AN INTRAPERITONEAL INJECTION IN SWINE

Equipment Needed:

1. Gravity flow intravenous set (for large hogs when dosage to be given is large) or a 25-cc or 50cc veterinary syringe (for pigs when dosage to be given is small).
2. Hypodermic needles, 16-gauge, at least 3 inches long for heavy hogs, 1 inch long for pigs.
3. Scissors or clippers.
4. 70% rubbing alcohol compound or other equally effective antiseptic for disinfecting the skin. Blue Lotion is ideal for this purpose.
5. The medication to be given.

Preparation of Equipment:

Thoroughly clean the needles and intravenous set or syringes and disinfect them by boiling in water for twenty minutes. Warm the bottle of medication to approximately body temperature and keep warm until used. If the injection is to be made with a syringe, swab the stopper with disinfectant before puncturing it with the needle. Use a separate needle for filling the syringe.

Procedure for Heavy Hogs

Area of Injection:

The place to make the injection is on the animal's right side at a point about 2½ inches below the loin muscles and midway between the last rib and the point of the hip. (See Fig. VII)

Preparation of Animal:

If necessary, restrain the animal by putting a noose in the mouth behind the tusks and pulling it tight around the upper jaw. Tie the free end of the rope to a post. Clip the hair from the area where the needle is to be inserted. Then swab the area vigorously with alcohol or other equally effective antiseptic to clean and disinfect the skin.

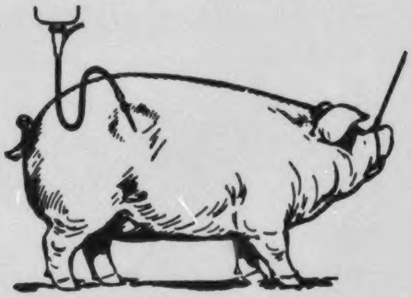


FIGURE VII

Inserting the Needle and Making the Injection:

At the point of injection described above, hold the needle perpendicular to the skin, thus directing it approximately toward the center of the body. Then with a quick thrust, insert the needle through the belly wall all the way to the hub. This will put the end of the needle into the peritoneal cavity.

While the needle is being placed in proper position, an assistant should get the medication ready by removing the rubber stopper from the bottle and attaching the intravenous tube to the neck of the bottle. Then invert the bottle and allow a small quantity of the solution to run through the tube to eliminate all air bubbles.

Connect the intravenous tube to the hub of the needle and elevate the bottle. If the needle is in proper position the solution will flow rapidly as indicated by a steady stream of bubbles entering the bottle through the air tube or valve. If the solution does not flow readily, disconnect the intravenous tube, withdraw the needle a short distance, and reinsert at the proper angle. If this fails to correct the trouble, the needle is probably clogged with a plug of tissue, in which case a new needle should be used.

Removal of the Needle:

After the proper dosage has been administered, pinch off the tube to prevent further flow, disconnect the tube, and quickly withdraw the needle. Then swab the site of the needle puncture with alcohol or other equally effective antiseptic.

Procedure for Pigs

(Suitable for any swine not too heavy to be handled)

Area of Injection:

The injection is made thru the belly wall at a point half way between the fold of the flank and the midline. (See Fig. VIII) In most pigs, this point lies between the rear nipple and the next nipple in front. The injection can be made either to the left or to the right of the midline.

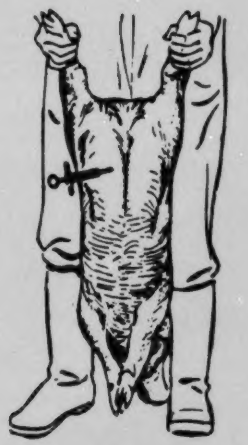


FIGURE VIII

Preparation of Animal:

The animal must be restrained by one of two methods: (1) An assistant holds the pig up by the hind legs, squeezing pig's body between assistant's knees to prevent movement. (2) The pig is placed on its back in a V-shaped trough and held down with the hind legs extended. In case the pigs are fairly large, two assistants may be required, one to hold the hind legs, and the other the fore legs. The trough should slope at an angle of 30 degrees or more with the pig's head at the low end of the trough. This sloping position practically eliminates the possibility of puncturing the intestine. Clip the hair from the area of injection and swab the skin with alcohol or other effective antiseptic to clean and disinfect the skin.

Inserting the Needle and Making the Injection:

After filling the syringe (use a separate needle) with the required dosage, attach a sterile needle, 16-gauge, 1 inch in length. At the point of injection described above, place the needle point against the skin, pointing it toward the center of the body. Quickly thrust the needle through the belly wall all the way up to the hub. Inject the full dosage and withdraw the needle. Swab the needle puncture with alcohol or more equally effective antiseptic and release the animal. If more than one syringeful is required, disconnect the syringe leaving the needle in place in the pig's belly. Refill the syringe, connect to the needle and make the second injection.

INTRAMUSCULAR: Injection is through the skin and subcutaneous tissue, directly into the muscle. Absorption is very rapid in this case.

DIRECTIONS FOR MAKING AN INTRAMUSCULAR INJECTION IN DOMESTIC ANIMALS

(Cattle, sheep, swine, horses and dogs)

Equipment Needed:

1. A 25 or 50cc veterinary syringe.
2. Hypodermic needle, 16 gauge, 3/4 to 1 inch in length.
3. Scissors or clippers.
4. 70% rubbing alcohol compound or other equally effective antiseptic for disinfecting the skin and bottle stopper. Blue Lotion

is ideal for this purpose.

5. The medication to be given.

Preparation of Equipment:

Clean and disinfect the needles and syringe by boiling in water for 20 minutes.

Areas of Injection:

An intramuscular injection is made directly into the muscle tissue or meat. Heavily muscled portions of the body such as the neck, shoulder and hindquarter should be utilized. Not more than 25-cc should be injected in any one spot in large animals--cattle, horses, and heavy hogs. In small animals--sheep, pigs, and dogs --not more than 10 to 15 cc should be injected in one spot. Where the dosage to be given is large, as much as 500 cc can be injected into cattle by distributing the dosage in 25-cc amounts into the heavy muscles of the neck, shoulder, and hindquarter on both sides.

Preparation of Animal:

Restrain the animal by the best means available. A stanchion or chute is ideal for large animals. Clip the hair from the area in which the injection is to be given and swab the clipped areas vigorously with alcohol or other equally effective antiseptic.

Inserting the Needle and Making the Injection:

Fill the syringe with the medication to be given, using a separate needle for filling. Disinfect the rubber stopper before inserting the needle into the bottle.

Insert a previously disinfected needle deeply into the muscle tissue with a quick thrust. Observe the hub of the needle for a moment. If blood begins to flow out of the needle, it is probably in a blood vessel and the needle should be withdrawn and re-inserted in a different direction. Attach the syringe to the needle and inject the medication slowly.

After the medication has been injected, remove the needle still attached to the syringe and massage the area with cotton soaked in alcohol so as to spread the medication through the muscle tissue. The above procedure is repeated in each injection area until the full recommended dose of medication has been given.

SUBCUTANEOUS: Injection into the tissue beneath the skin.

DIRECTIONS FOR MAKING A SUBCUTANEOUS INJECTION IN DOMESTIC ANIMALS

(Cattle, sheep, swine, horses and dogs)

First, read directions for making an intramuscular injection. The equipment needed, its preparation, and preparation of the animal are the same as for an intramuscular injection.

A subcutaneous injection is an injection made beneath the skin, i.e., between the skin and the muscle tissue. The recommended areas of injection are places where the skin is loose, particularly on the sides of the neck and behind the shoulder. In pigs and sheep the axillary space is frequently used for subcutaneous injection. The axillary space lies between the foreleg and the chest wall, and corresponds to the armpit in man.

To make the injection, pinch up a fold of skin between the thumb and fingers (not necessary if axillary space is used). Insert the needle under the fold in a direction approximately parallel to the surface of the body. When the needle is inserted in this manner, the medication will be delivered underneath the skin between the skin and the muscles. Observe the same precautions regarding clipping and disinfecting the skin as outlined under intramuscular injections.

ORAL: By the mouth--drugs are usually given by the mouth and are absorbed in the stomach and intestines. Absorption is more rapid when drugs are given in solution into an empty stomach; slower when administered in powder, pill or ball form, and on a full stomach.

OTHER METHODS OF ADMINISTERING DRUGS

INHALATION: (Inhale). Volatile drugs are used mainly for their local action on the respiratory tract.

RECTAL: By the rectum. This method is used when oral administration is inadvisable or impossible, because of paralysis of the throat, etc. Absorption here is slower.

TOPICAL: Local application to external surfaces of the body: Absorption by this method is extremely slow and the effects of the drug are limited to the treated area.

BODY TEMPERATURE

Average Rectal Temperature

Horse	100.2
Ass	98.5
Cow	101.5
Sheep	102.3
Goat	103.8
Pig	101.7-103.3
Dog	101.0-102.0
Cat	101.7
Fowl	106.9-109.0
Duck	107.8-110.5

CATTLE DISEASES

Disease: Acetonema

Cause: Metabolic disturbance occuring as a complication of milk fever or as a result of poor winter feeding.

Symptom: Reduced milk flow, constipation and rapid loss of weight.

Treatment: Subcutaneous injection of 250 to 500 c.c. of Sterile Glucose Solution repeated in 24 hours if needed.

Prevention: Provide molasses, high-quality hay and/or good pasture grasses.

Disease: Actinomycosis (Lump Jaw) and Actinobacillosis (Wooden Tongue)

Cause: Fungus organisms.

Symptom: Tumor-like swellings or enlargements of tissues about the head and throat. Swellings contain yellowish-white pus.

Treatment: Intravenous injection of 500 c.c. of Sodium Iodide per 1,000 pounds animal weight.

Prevention: Mix one pound organic Iodide compound with 50 pounds of salt and feed free choice.

Disease: Anaplasmosis

Cause: Protozoan blood parasite.

Symptom: Anemia as shown by loss of appetite, loss of flesh, and yellowish discoloration of visible mucous membranes.

Treatment: Intramuscular injection of Sodium Cacodylate Solution; 5 c.c. for each 100 pounds body weight. In cases of exhaustion also give 100 c.c. of Sterile Glucose Solution.

Prevention: Control flies and other insects by spraying.

Disease: Anthrax

Cause: Bacterium passed in contaminated feed or water.

Symptom: Spasm, staggering, and death within a few hours. Rapid decomposition occurs after death and blood fails to clot.

Diagnosis: Laboratory blood analysis.

Treatment: 100 to 250 c.c. of Anti-Anthrax serum should be given daily until animal's body temperature returns to normal. Supplement large doses of Penicillin every 4 hours.

Prevention: Vaccination every 2-1/2 to 3 months if anthrax is known to the area. Burn and bury all dead animals.

Disease: Blackleg

Cause: Bacterium

Symptom: Lameness, stiffness, and possible bloody discharge. Death is rapid.

Treatment: Not practical.

Prevention: Calfhood vaccination of one 5 c.c. dose of Blackleg Bacterin whole culture (Alum Treated). Burn and bury dead animals.

Disease: Brucellosis

Cause: Infectious disease which acts on the genital tract. Spreads by breeding of infected animals.

Symptom: Abortion.

Diagnosis: Blood Test.

Treatment: None.

Prevention: Calfhood vaccination with Brucella Abortus Vaccine - 5 c.c. per animal, sterilizing all syringes and needles between each vaccination.

Disease: Calf Diphtheria

Cause: Actinomyces necrophorus infection.

Symptom: Infected larynx -- high temperature, distressed breathing, and death due to strangulation. Infected mouth -- emaciation and salivation.

Treatment: Intraperitoneally administer 25 c.c. per 100 pounds of Triple-Sulfa solution. Segregate sick animals.

Prevention: Clean and disinfect all water and feed containers; generally clean the animal area.

Disease: Calf Scours (White Scours)

Cause: Colon bacillus present in the digestive tract.

Symptom: Grey or white fluid diarrhea which has an offensive odor.

Treatment: One Calf Scour Bolus for each 50 pounds of body weight. If serious, inject 50 to 100 c.c. of Antibacterial Serum (Bovine) also give injections of Vitamins A-D-E in oil solution.

Prevention: Sanitation.

Disease: Foot Rot

Cause: Injury to feet with subsequent infection.

Symptom: Slight lameness to complete rotting of the hoof.

Treatment: Triple-Sulfa solution given intravenously or intraperitoneally.

Prevention: Mix one pound organic Iodide compound with 50 pounds salt and feed free choice.

Disease: Hemorrhagic Septicemia (Shipping Fever)

Cause: Lowered resistance making the animal subject to Pasteurella organisms.

Symptom: Cough, difficult breathing, temperature, staggering, and death. Dead animals have blood spots on the heart, lungs and intestinal membranes.

Treatment: Isolation and 100 to 500 c.c. dose of Anti-Hemorrhagic-Septicemia Serum, repeated in 24 hours as needed.

Prevention: Calfhood vaccination (whole Culture) using a 5 c.c. dose.

Disease: Cowpox

Cause: Filterable virus picked up through the skin of susceptible animals.

Symptom: Inflamed areas on upper teats and inner surface of thighs. Bumps and blisters may be present.

Treatment: The disease will run its course but Sulfa lotion aids healing of Cowpox sores.

Prevention: Isolate sick animals.

EXTERNAL PARASITES OF CATTLE

Parasites: Horn flies, lice, gnats, mosquitoes and cattle grubs.

Treatment: Malathion, DDT, Chlordane, and Lindane. Treatment may be given by spraying or dipping. Methods of application should follow the recommendation for the product used.

Parasite: Screw Worms

Cause: Screw worm fly lays eggs which hatch into small larvae or worms that burrow into raw tissue.

Symptom: Raw open wound with worms inside.

Treatment: Use a liquid screw worm killer containing Benzol and Chloroform.

CATTLE BLOAT

Cause: Accumulation of excessive gas in the paunch created by changes in feed, overeating or mechanical problems.

Treatment: Two ounces of Equi-Dine mixed with a pint of Mineral Oil given as a drench. For acute cases puncture the paunch by cutting a hole in the upper left flank midway between the last rib and the point of the hip.

CATTLE INDIGESTION

Cause: Spoiled or damaged feeds and other indigestible substances.

Treatment: Empty the digestive tract by giving 2 ounces of Purgative every 6 hours for 3 doses or until relief occurs.

INTERNAL PARASITES OF CATTLE

Parasites: Stomach worms, nodular worms, hook worms, lung worms, and liver flukes.

Treatment: Pasture rotation and Phenothiazine used in a drench or feed. Use one ounce per 100 pounds body weight up to a maximum of six ounces.

OTHER CATTLE DISEASES

Disease: **Leptospirosis**

Cause: Germ called leptospira.

Spread: Through urine of infected animals.

Symptom: Sudden abortion, anemia, yellowish color, and blood-tinged milk.

Treatment: None effective.

Prevention: Sanitation and vaccination with Leptospira Pomona Bacterin. Vaccinate calves at 3 to 6 months of age and each year thereafter.

Disease: **Malignant Edema**

Cause: Clostridium septicum organism.

Symptom: Similar to Blackleg with a higher fever.

Treatment: Massive doses of penicillin.

Prevention: 5 c.c. dose of Triple Bacterin.

Disease: **Mastitis**

Cause: Streptococcus.

Symptom: Sudden decrease of milk and lumpy, stringy or bloody milk.

Treatment: Use Sulfanilamide-in-oil as an intramammary infusion. Milk frequently until cured and apply hot epsom salt water packs as needed.

Prevention: Sanitation and control of flies.

Disease: Metritis

Cause: Bacterial infection in the uterus.

Symptom: Vaginal discharge, straining and loss of weight.

Treatment: Sulfanilamide uterine boluses. Use 3 to 6 boluses and repeat in 24 hours if needed.

Prevention: Sanitation at calving. Assist, as needed, the removal of the afterbirth.

Disease: Milk Fever

Cause: Unknown.

Symptom: Nervousness, spasm and then collapse. Neck assumes S-like curve.

Treatment: Cal-O-Dex or Cal-D-Mag. Administer 250 to 500 c.c. intravenously and repeat in 12 to 24 hours if needed.

Prevention: Provide adequate mineral supplements especially during pregnancy.

Disease: Pink Eye

Cause: Streptococci and Staphylococci with mineral and vitamin deficiencies as a predisposing factor.

Symptom: Closed eyes, reddened eyelids, and white scum over the eyeballs.

Treatment: Pink-Eye powder; a mixture of Sulfanilamide, Boric Acid, Acriflavin, and Sulfathiazole sodium.

Prevention: Unknown.

Disease: Pneumonia

Cause: Infectious disease of the lungs brought on by chilling, crowding and malnutrition.

Symptom: Rapid breathing, high fever and loss of appetite. Lesions are found in the lungs of dead animals.

Treatment: 240-grain boluses of Sulfathiazole every 8 hours as needed. Give daily injections of 1 to 3 c.c. of Vitamin A-D-E.

Prevention: Avoid exposure to cold, crowding and malnutrition.

Disease: Red Water Disease

Cause: Bacillary Hemoglobinuria which is found in swampy and poorly-drained areas.

Symptom: Dark urine, high temperature and sudden death. Dead animals show signs of hemorrhaging on the membranes lining the chest and abdomen.

Treatment: None.

Prevention: Vaccinate all animals in infected territories with Red Water vaccine. (Clostridium-Hemolyticum Bacterin)

PRUSSIC ACID POISONING

Cause: Hydrocyanic acid animals obtain by eating the second growth of canes and sorghums.

Symptom: Muscular trembles, staggering, and sudden death.

Treatment: 30 to 60 c.c. of Thio-Nitro Solution, intravenous.

Prevention: Keep animals away from second growths of cane or sorghums.

WARTS

Cause: Filterable virus.

Symptom: Wart growth on any part of the body.

Treatment: Culling, sanitation, and use of Wart Vaccine (Bovine origin)

Prevention: Sanitation and culling of warty animals.

WHEAT POISONING and GRASS TETANY

Cause: Fast growing young wheat or grass.

Symptom: Incoordination, loss of appetite and staggering. Convulsions, with periods of relaxation, occur before the animal dies.

Treatment: 500 c.c. of calcium gluconate by slow intravenous injection.

Prevention: Control grazing of young wheat or grasses.

PENICILLIN INTRAMUSCULAR DOSAGE FOR CATTLE

(Milk unpotable until a week after last dose)

General Rule: Allow 1 c.c. to each 100 pounds body weight. Use 16 gauge 1-1/2 inch needle. Give daily for infections until 2 days after symptoms disappear.

SWINE DISEASES

Disease: Anemia

Cause: Lack of magnesium, manganese, cobalt and zinc. Deficiencies often result from pigs being farrowed on concrete or wooden floors which prevents their access to the soil.

Symptom: Sluggishness and difficult breathing.

Treatment: Intramuscular injection of 2 c.c. of Swi- Ron (Sterile Iron solution)

Prevention: Give pigs access to soil or inject 2 c.c. of Swi-Ron per pig at 2-4 days of age.

Disease: Brucellosis

Cause: Brucella suis. (Genital Disease)

Symptom: Abortion and lameness.

Diagnosis: Blood Test

Treatment: None

Prevention: Cull infected animals

Disease: Swine Erysipelas

Cause: Germ, Erysipelothrix rhusiopathiae.

Symptom: Red discolorations on skin, difficult breathing, high temperature, and swollen joints.

Treatment: Anti-Swine-Erysipelas Serum, 5 c.c. for pigs up to 50 pounds and proportionate increases up to 20 c.c. for over 100 pounds.

Prevention: Vaccinate all swine every 6 months with Erysipelas Bacterin, 5 c.c. up to 100 pounds and 10 c.c. over 100 pounds. Sows and gilts should be vaccinated 4 to 6 weeks before the farrowing period.

Disease: Hemorrhagic Septicemia

(See Cattle Section)

Disease: Swine Flu

Cause: Filterable virus affecting the respiratory tract.

Symptom: Coughing, temperature, and difficult breathing. Dead animals have a heavy mucus in the Bronchi.

Treatment: Provide warm, dry quarters and inject 2 to 5 c.c. of Vitamins A-D-E injectable oil solution.

Prevention: Provide warm, dry quarters during cold and rainy seasons.

Disease: Hog Cholera

Cause: Filterable virus.

Symptom: Wobbly gait, red and watery eyes, difficult breathing and diarrhea. Dead animals have bright red spots on kidneys, bladder, lungs, and lymph glands.

Treatment: None effective.

Prevention: Vaccinate each animal with 5 c.c. of crystal Violet Hog Cholera vaccine. Pigs should be 6 weeks old before vaccination. Always place vaccine under the skin of the foreleg. (Anti-Hog-Cholera serum may be used to provide quick immunity lasting only about 3 weeks, however, there is a danger that serum may interfere with later development of good immunity.)

Disease: Enteritis

Cause: Food upset or dietary deficiency.

Symptom: Loose bowel movements often black or bloody.

Treatment: Feed animal protein to provide B vitamins, Niacin, Riboflavin, and Calcium Pantothenate. Practice sanitation by providing clean food and water.

Disease: Infectious Enteritis

Cause: Vibrio - Necrotic - Necro - Bacterial and Generalized Septicemia are all causative organisms.

Symptom: Bloody diarrhea, watery diarrhea, or other diarrhea.

Treatment: Sodium Arsanilate added to drinking water, feed some whole oats or bulky feed, put Sulfaquinoxaline in drinking water, and use antibiotics plus penicillin.

Prevention: Sanitation and proper diets.

Disease: Leptospirosis

Cause: Leptospira pomona.

Symptom: Abortion and litters with some dead or stunted animals.

Treatment: None effective.

Prevention: Vaccinate with Leptospira Pomona Bacterin and cull all diseased animals.

SYMPTOM TABLE

ARE THEY AFFECTED WITH HOG CHOLERA, SWINE ERYSIPELAS, OR INFECTIOUS GASTROENTERITIS?

Examine These Organs:	Acute Hog Cholera	Acute Swine Erysipelas	Acute Infectious Gastroenteritis
SKIN	Red Spots or Hemorrhages do not disappear on pressure	Scarlet areas--disappear on pressure; "diamond skin"	Normal or extensive purple discoloration of abdomen just before death
EYES	Eyelids gummy	Normal or clear watery discharge	Normal
LIMBS	Knuckle at pastern joints	Hot, painful and frequently swollen	Normal
EPIGLOTTIS	Small petechial hemorrhages	Normal	Irregular size hemorrhages may be present
LYMPH GLANDS	Bright red, enlarged, and congested at borders	Little change in color but enlarged	Enlarged, congested, purplish-black in color
LUNGS	Real dark hemorrhages that do not run together are present	Normal; may be scattered areas of congestion	Usually scattered areas of congestion

SYMPTOM TABLE

ARE THEY AFFECTED WITH HOG CHOLERA, SWINE ERYSIPELAS, OR INFECTIOUS GASTROENTERITIS?

Examine These Organs:	Acute Hog Cholera	Acute Swine Erysipelas	Acute Infectious Gastroenteritis
STOMACH	Membranes usually normal.	Contains some food; membranes frequently show patchy areas of congestion and heavy sticky mucus on surface.	Contains foul-smelling ingesta. Usually acute, diffuse inflammation.
SPLEEN	Normal or slight enlargement or discoloration along edges; dark.	Frequently normal; may show slight enlargement with reddish-purple discoloration.	Enlarged, friable, dark red or purplish-black in color.
LIVER	Normal or may be congested.	Usually normal.	Frequently enlarged and congested.
SMALL INTESTINES	Normal or slight congestion.	Frequently congested.	Usually congested; may show petechial hemorrhages on mucous membrane.
LARGE INTESTINES	Generally shows moderate congestion, especially in region of ileocecal valve.	Usually normal.	Usually diffuse congestion of mucous membrane over large area.
KIDNEY	Pin-point petechial hemorrhages.	Usually some inflammation present.	Soft and congested. Petechial hemorrhages large and irregular in size.
BLADDER	Petechial hemorrhages or congestion of mucous membrane.	Usually normal or slight congestion.	Numerous hemorrhages, irregular in size; extensive diffuse congestion.

EXTERNAL PARASITES OF SWINE

Parasite: Mange (Mite)

Treatment: 0.046 per cent Lindane or 3 tablespoons of Lindane to 2-1/2 gallons of water to be used as a spray or dip.

Parasite: Hog Louse

Treatment: A-D-A Lice powder and spraying or dipping with Malathion compound.

INTERNAL PARASITES OF SWINE

Parasite: Ascarids (Roundworms)

Treatment: Keno caps which contain Oil of Chenopodium. For pigs 40 to 80 pounds give one cap, over 80 pounds give 2 caps. Pen animals 18 to 24 hours; withhold feed and water for 3 hours after treatment.

Parasite: Thorn-headed Worms

Treatment: None

Prevention: Ring noses of pigs to prevent rooting.

Parasite: Nodular Worms

Treatment: Phenothiazine (Drench grade) with Bentonite. 5 grams for 25 pound pigs up to 30 grams for 200 pounds and over.

PENICILLIN INTRAMUSCULAR DOSAGE FOR SWINE

General Rule: Allow 1/2 c.c. up to 10 pounds; 1 c.c. up to 50 pounds, and 2 to 3 c.c. for hogs between 100 to 200 pounds. Use 16 or 18 gauge one inch needle. Give daily for infections until 2 days after symptoms disappear.

VITAMIN DEFICIENCY SYMPTOMS

General Rule: All young are born with low reserves of Vitamins A, D, and E. Weakness, unthriftiness and emaciation are immediate symptoms.

Vitamin A - is obtained from green feeds and sun-cured roughage. Swine deficient in A vitamin show slow growth, lameness and will often have diarrhea.

Vitamin D - is provided in sunshine. Deficient animals have enlarged joints, abnormal walking, and humped back.

Vitamin E - acts as an anti-oxident. It stabilizes vitamin A and increases its utilization by the animal.

SHEEP DISEASES

Disease: Enterotoxemia

Cause: Organism, Clostridium perfringens Type D. (Affects Lambs)

Symptom: Walking in circles, leaning, throwing head back, convulsions and coma. Dead animals show hemorrhages of the heart.

Treatment: None effective. Antitoxin may be helpful at early stages.

Prevention: 5 c.c. injection of Type D Bacterin under the skin; Lambs should be at least 2 months old. Wait 4 weeks after vaccination before slaughtering. Reduce the quantity of feed if the disease is suspected.

Disease: Pink Eye

Cause: Contagious disease associated with vitamin A deficiency.

Symptom: Eyes water, swell and become inflamed.

Treatment: Isolation, dark quarters, green feed, and pink eye prescription.

Prevention: Green feed.

Disease: Lambing Paralysis

Cause: Toxemia resulting from lack of exercise.

Symptom: Slowness, leaning, paralysis of hindquarters and death within 6 or 7 days of onset. Dead animals have lesions on liver.

Treatment: Daily injections of 40 to 50 c.c. of Sterile Glucose Solution.

Prevention: Exercise and good feeding for pregnant animals.

Disease: Soremouth

Cause: Contagious Ecthyma

Symptom: Tiny blisters on lips which grow and become filled with pus. These eventually scab and dry if no complications develop.

Treatment: None

Prevention: Vaccination with Ovine-Ecthyma.

Disease: Stiff Lambs

Cause: Unknown (possibly Metabolic)

Symptom: Lambs show stiffness, muscular tremors and inability to rise.

Treatment: 10 c.c. of Wheat Germ oil with 2 ounces milk - daily until improvement is noted.

EXTERNAL PARASITES OF SHEEP

Parasite: Sheep Scab (Mange)

Cause: Mange mites.

Symptom: Unthrifty animals that rub and scratch.

Treatment: Lindane mixed the same as for Hog Mange.

Prevention: Quarantine and examine new animals for 10 days.

Parasite: Goat Lice

Treatment: 1 part malathion to 10 parts water or A-D-A Lice powder.

Parasite: Sheep Ticks

Cause: Wingless Fly

Symptom: Off feed and restless.

Treatment: Two-tenths per cent DDT emulsion.

Parasite: Sheep Nasal Fly

Cause: Larvae of Sheep Botfly.

Symptom: Sheep run with nose to ground during fly season.

Treatment: None.

Prevention: Smear Pine Tar on the nose.

Parasite: Foot Rot (Fungus)

Symptom: Redness and swelling of the skin above the hoof. Lameness.

Treatment: Trim feet removing loose hoof and bathe in Copper Sulfate dissolved in water - if solution is strong one or two minutes is enough. Apply a suitable antiseptic.

Prevention: Keep infected animals away from clean flocks. Sheep should be on dry ground.

INTERNAL PARASITES OF SHEEP

Parasites: Same as Cattle

Symptom: Anemic reaction. Sheep become weak and stunted; often have swollen stomach or jaws.

Treatment: Phenothiazine drench, boluses or feed mix. Lead Arsenate may be needed for tapeworms.

PENICILLIN INTRAMUSCULAR DOSAGE FOR SHEEP

General Rule: Lambs up to 10 pounds, 1/4 to 1/2 c.c.; 10 to 20 pounds, 1/2 to 3/4 c.c.; 20 to 60 pounds, 3/4 to 1 c.c.; for 100 pounds use 1 to 2 c.c. Use 18 gauge one inch needle. Give daily for infections until 2 days after symptoms disappear.

HORSE DISEASES

Disease: Colic

Cause: Improper feeds.

Symptom: Restlessness and kicking at the stomach.

Treatment: Equi-Dine

Prevention: Controlled feeding methods.

Disease: Sleeping Sickness

Cause: Filterable virus affecting the brain and spinal cord.

Symptom: Animals are first excited and then depressed. Facial paralysis and spasms of the lips precede muscular tremors, coma, and finally death.

Treatment: 250 c.c. of Anti-Encephalomyelitis Serum.

Prevention: Two interadermic injections of Encephalomyelitis Vaccine.

Disease: Fistula and Poll Evil

Cause: Bruising of tissues; back of the head for Poll Evil and on the withers for Fistula. Bacterial factors may create complications.

Symptom: Swelling on poll or withers which enlarges as it fills with flocculent pus.

Treatment: Cut the abscess at the lowest part to establish drainage. Irrigate daily with an odorless disinfectant (1 oz. to 1 gallon of water). Feed a mineral ration mixed with a tonic powder containing arsenic. (1 teaspoonful of tonic to a quart of oats or bran to be added to regular ration)

Prevention: Careful handling.

Disease: Influenza

Cause: Infectious and contagious filterable virus brought on by fatigue and exposure.

Symptom: Chills, coughing and mucous discharge from the nose. Complications may occur in the form of diarrhea, pneumonia and sore joints.

Treatment: None specific. Give injections of Camphoil and Sterile Glucose Solution.

Prevention: Sanitation and quarantine. Provide warm, dry quarters.

Disease: Navel Ill

Cause: Variety of organisms.

Symptom: Colts appear weak, breathe hard, have swollen joints and die within a few days.

Treatment: 100 to 150 c.c. of Normal Serum (Equine Origin) given daily as needed.

Prevention: Sanitation and painting of colt's navel with iodine.

Disease: **Distemper**

Cause: Pyogenic Streptococcus which invades tissues around the head and throat.

Symptom: Fever, discharge from the nose and swelling under the jaw with abscesses appearing in 1 to 2 weeks.

Treatment: Fresh water, rest, puncture abscesses when soft, and give Triple-Sulfa Boluses or solution.

Prevention: Segregate new or sick animals.

Disease: **Tetanus**

Cause: Clostridium tetani which enters tissue through wounds.

Symptom: Stiffness, anxiousness and extreme nervousness. Stiffness of the jaw muscles to the point that eating is impossible.

Treatment: 40,000 to 100,000 units of Tetanus Antitoxin for the first day. 1,500 unit doses 2 to 3 times daily after the initial dose until the animal responds. Paint wound with iodine.

Prevention: If an animal is wounded give 1,500 units of Tetanus Antitoxin.

EXTERNAL PARASITES OF HORSES AND MULES

Parasites: Flies, lice and ticks.

Control: Sponge on barn or livestock sprays, being careful that you do not wet skin. DDT emulsion is good for flies and lice. Use Chlordane emulsion to control ticks.

INTERNAL PARASITES OF HORSES AND MULES

Parasites: Bot larvae, ascarids and strongyles are most common.

Control: For ascarids (round worms) use one 6 gram Equine Worm Capsule. Phenothiazine is effective in removing strongyles. Bot larvae are difficult to control.

PENICILLIN INTRAMUSCULAR DOSAGE FOR HORSES AND MULES

General Rule: Horses and foals up to 500 pounds use 5 c.c.; 500 to 1000 pounds use 5 to 10 c.c.; 1000 to 2000 pounds use 10 to 20 c.c. Inject in the rump and use 16 gauge needle 1-1/2 to 2 inches long. Give daily for infections until 2 days after symptoms disappear.

DOG DISEASES

Disease: Distemper

Cause: Filterable virus for first stage and bacteria for second stage.

Symptom: Fever, loss of appetite, diarrhea, vomiting, coughing and yelping.

Treatment: Difficult, attempt care and nursing.

Prevention: Canine Distemper Vaccine for healthy animals.

Disease: Ear Canker

Cause: Species of mite.

Symptom: Pawing and rubbing of ears and shaking of head.

Treatment: Remove scales and wax with cotton swab, then pour a small quantity of ear canker emulsion into the canal. After rubbing the ear wipe off excess. Repeat in 30 days.

Prevention: None.

Disease: Rabies

Cause: Virus disease transmitted by the bite of a rabid animal.

Symptom: Animals are irritable, attack objects in their path, paralysis develops in hind quarters and death follows.

Treatment: None.

Prevention: Annual vaccination of all dogs with rabies vaccine.

Disease: Running Fits

Cause: Unknown condition affecting the nervous system of dogs.

Symptom: Animal barks, runs wildly and champs at the jaw.

Treatment: Good diet and dark quiet quarters.

Prevention: Unknown.

Disease: Eye Irritations

Cause: Foreign matter, injuries, colds and fever.

Symptom: Check the eyes for unusual conditions

Treatment: Remove the cause and apply an eye wash containing Zinc Sulfate and Butyn Sulfate.

EXTERNAL PARASITES

Parasites: Fleas, lice, and ticks.

Control: Flea bomb or powder. Washing and removal by hand will help if nothing else.

Parasite: Mite (Mange)

Control: Mange remedy or 1/4% Chlordane emulsion. Disinfection of quarters and a good diet are helpful.

NUTRITIONAL DISORDERS

Problem: Poor condition

Control: Provide minerals, vitamins and high quality proteins.

INTERNAL PARASITES

Parasites: Roundworms, hookworms, and tapeworms

Control: Tetrachlorethylene for roundworms and hookworms. Use Arecoline Hydrobromide for tapeworms.

Prevention: Sanitation and disinfection.

POULTRY DISEASES

Management and Hygiene: Establish sanitation procedures. Adequate housing should be provided with provision for keeping chicks warm. Housing should be dry with adequate space and ventilation. Feed and water should be clean. Where disease is a problem disinfectant should be added to the drinking water. A good general disinfectant is 20% Quaternary Ammonium compound.

Nutritional Diseases:

Disease: Roup (Avitaminosis A)

Cause: Deficiency of Vitamin A.

Symptom: Cessation of growth, weakness, rough feathers and a staggery gait. Adult birds accumulate a cheesy material in the eyes. Dead birds show white pustules in the lining of the gullet.

Treatment and Prevention: Vitamin A foods such as fish liver oils and green feed.

Disease: Rickets

Cause: Vitamin D deficiency.

Symptom: Soft bones, deformities, beak is soft and birds lay soft shelled eggs.

Treatment and Prevention: Sunshine and a balanced diet.

Disease: Slipped Tendon

Cause: Lack of Manganese or a deficiency of Choline.

Symptom: Flattening of hock joints causing the tendons to slip to one side and turn the foot in or out.

Treatment: None.

Prevention: Mineral supplement or tablets.

Bacterial Diseases:

Disease: Bluecomb

Cause: Gastro-intestinal disease.

Symptom: Affects turkeys causing darkening of skin on the head and neck. A greenish or yellowish diarrhea is usually seen

Treatment: 1 gram per gallon of water of Streptomycin Sulfate Powder.

Disease: Limberneck

Cause: Toxin from Clostridium Botulinus. Usually develops from decomposing material upon which maggots are found.

Symptom: Toxin produces paralysis.

Treatment and Prevention: Sanitation and a clean range. Give one pound of Epsom salts dissolved in water for each 100 adult birds.

Disease: Erysipelas (Turkeys)

Cause: Bacterial disease.

Symptom: Swollen snoods and hemorrhaging in the muscles.

Treatment: Feed tetracycline antibiotic for 7 days. Inject 40,000 to 60,000 units of procaine penicillin in aqueous suspension.

Prevention: Vaccination after 8 weeks of age.

Disease: Fowl Cholera

Cause: Pasteurella avisepticus.

Symptom: Dying birds which may or may not show swollen wattles or diarrhea before death. Dead birds show hemorrhaging on the band of fat around the heart.

Treatment: 1-1/2 ounces of Sulfaquin-oxaline solution for each gallon of drinking water for 3 days.

Prevention: Burn dead birds and isolate sick birds. Vaccinate susceptible birds with Avisepticus-Gallinarum Bacterin.

Disease: Chronic Respiratory

Cause: Bacteria or Virus (air-borne)

Symptom: Sneezing, coughing and hacking. Feed consumption drops and egg production falls off.

Treatment: Dissolve Streptomycin Sulfate powder in drinking water.

Prevention: None

Disease: Fowl Typhoid

Cause: Acute septicemic disease.

Symptom: Yellowish or greenish diarrhea, thirst and general emaciation.

Treatment and Prevention: Disinfection, isolation of sick birds and vaccination with Avisepticus-Gallinarum Bacterin.

Disease: Infectious Coryza (Chickens)

Cause: Cold bacterium.

Symptom: Nasal discharge to coughing and sneezing. Egg production is reduced.

Treatment: Streptomycin Sulfate powder in drinking water and a source of vitamin A.

Prevention: Green feeds and good ventilation of poultry houses.

Disease: Paratyphoid

Cause: Salmonella organisms.

Symptom: Not positive; resembles other diseases. Dead birds have enlarged livers.

Treatment and Prevention: Vaccination of healthy birds with Gallinarum-Typhimurium Bacterin.

Disease: Pullorum

Cause: Bacterial infection of the ovaries.

Symptom: New chicks appear sleepy and weak. Whitish diarrhea and gasping for breath precedes death.

Treatment: None.

Prevention: Blood testing, disinfection, fumigation and burning of dead chicks.

Disease: Tuberculosis

Cause: Contagious disease.

Symptom: Emaciation, anemia, lameness and paralysis.

Treatment and Prevention: None.

Disease: Aspergillosis

Cause: Infectious disease of the respiratory system.

Symptom: Rapid breathing and eventual emaciation. Dead birds show small nodules in lungs.

Treatment: None.

Prevention: Avoid moldy feed and wet or damp surroundings.

Disease: Mycosis of the Crop

Cause: Fungus infection of the crop.

Symptom: Birds are listless, droopy and fail to gain weight.

Treatment: At intermittent periods of 3 to 4 days add one level teaspoonful of copper sulfate to each 2 gallons of drinking water.

Prevention: Avoid wet feed or litter.

Disease: Fowl Pox

Cause: Filterable virus often transmitted by mosquitoes.

Symptom: Wart-like growths on the comb and wattles.

Treatment: Paint cankers with iodine.

Prevention: Vaccinate with Fowl-Pox vaccine.

Disease: Infectious Bronchitis

Cause: Filterable Virus

Symptom: Gasping followed by depression and weakness.

Treatment: None.

Prevention: Bronchitis vaccine mixed in drinking water.

Disease: Laryngotracheitis (Chickens)

Cause: Filterable virus.

Symptom: Wheezing, gurgling and rattling in the throat. Death is from suffocation; birds show a dense cheesy material in the windpipe.

Treatment: None.

Prevention: Sanitation and quarantine. Laryngotracheitis vaccine may be used, but the virulent virus is a possible hazard to the user.

Disease: Leucosis (Chickens)

Cause: Filterable virus.

Symptom: Paralysis, grey eyes, and large livers with lymphoid tumors. (Birds usually have only one of the above symptoms.)

Treatment: None.

Prevention: Feed adequate rations, control internal and external parasites.

Disease: Newcastie

Cause: Filterable virus.

Symptom: Gasping followed by various nervous disorders.

Treatment: None.

Prevention: Newcastle disease vaccine (For intranasal, intraocular, or drinking water use)

Disease: Blackhead (Turkeys)

Cause: Protozoan.

Symptom: Poults are weak, sleepy, and droopy. Inflamed liver and ceca.

Control: Use Blackhead formula soluble in water for 1 to 2 weeks.

Prevention: Continuous use of Balckhead Formula. Control cecal worms.

Disease: Coccidiosis

Cause: Eimeria tenella protozoan parasite.

Symptom: Bloody droppings, dull and droopy birds which may soon die from hemorrhaging.

Control and Prevention: Sulfaquinoxaline solution in drinking water.

Disease: Trichomoniasis (Turkeys)

Cause: Protozoan.

Symptom: Ruffled feathers and foul-smelling saliva.

Treatment: One teaspoonful of copper sulfate in 2 gallons of drinking water for four days; skip three days and repeat if needed.

Prevention: Avoid poorly drained or infected areas.

Cannibalism: Habit acquired by confined birds.

Control: Salt in drinking water, ample space and green feed.

Internal Parasites

Parasites: Roundworm, tapeworm and cecal worm are most significant.

Control: Nicotine, Phenothiazine, and Piperazine hydrochloride.

External Parasites

Parasites: Lice, mites, and blue bugs.

Control: Lindane, Malathion or powders containing Rotenone, Sulfur, and petroleum oil.

EXTERNAL SYMPTOMS OF BIRDS		PROBABLE CAUSE
Eyes and Nostrils	Mucus	Infectious Coryza (Colds) Avitaminosis A
	Cheesy Material	Bacterial Roup
	Blindness	Leucosis
Breathing	Gasping	Laryngotracheitis Heat Prostration Pneumonia
Comb	Dark Red	Fowl Cholera Blackhead Intestinal Parasites
	Pale	Tuberculosis Fowl Typhoid Fowl Leucosis
	Scabs	Fowl Pox

EXTERNAL SYMPTOMS OF BIRDS		PROBABLE CAUSE
Feathers	Ruffled	Intestinal Parasites Lice Coccidiosis
Wings	Drooped	Severe Parasitism Pullorum Disease Coccidiosis Blackhead
Loss of Flesh		Tuberculosis Intestinal Parasites Fowl Leucosis
Legs	Paralysis or Weakness	Avitaminosis A or D Coccidiosis Fowl Leucosis Botulism
Neck	Limber	Cholera (Late Stages) Botulism
Diarrhea	Yellowish-Brown	Cholera Blackhead
	Green	Fowl Typhoid Fowl Leucosis
	Bloody	Coccidiosis
	Whitish	Pullorum Disease Intestinal Parasites

AQUICULTURE

CONSTRUCTION OF PONDS

Farm fish ponds, under proper management, can contribute materially to a nation's food supply. This is particularly true in southern countries where most pondfishes attain within one year sufficient size for table use. Farmers who own a pond site will find that with a little labor and non-critical materials they can build a small fish pond which will produce enough fish to supplement their meat supply and furnish minerals and vitamins required in the diet to maintain health. A farm fish pond one acre in size, properly fertilized and managed, can supply up to 200 or more pounds of fish a year. Production will be reduced in northern regions in proportion to the shortening of the growing season and lower water temperatures.

POND OR WATER AREA

The selection of the pond site is important. Primary considerations are: an adequate but not excessive water supply, a pond bottom which will hold water, a location where the dam can be constructed economically, and satisfactory and sufficient materials nearby with which to build the embankment. Secondary considerations are: reasonably fertile soil for the pond bottom, erosion control on the watershed area, gently sloping ground particularly for the pool area, and freedom from heavy overflow or flash floods. Low areas too wet to farm often make ideal pond sites for wildlife and fish.

The source of water for the pond should receive first consideration. In order to reduce the cost of construction and of fertilization after the pond is full, it is best to consider only small streams or springs or direct runoff from pastures and woodlands. It is not necessary to have a constant overflow from the pond but there must be sufficient water to fill the pond and to maintain it at a rather stable level. If it is impossible to find a site where water is flowing during the summer months, then the pond should have sufficient depth to provide adequate space for the fish when evaporation lowers the amount of water-surface. A ratio of approximately 10 to 15 acres of watershed to one surface acre of pool water should be established for pasture land when the water source is only direct rainfall runoff, with a slightly larger ratio for woodland and a smaller one for lands under cultivation. These ratios will, of course, vary with the rainfall and the slope of the land, so they should be determined for each pond.

After the general location has been chosen with respect to the water supply, the next step is to select the actual site for the pond and dam. Areas where gravel beds exist or where limestone outcrops are present should be avoided as the ground may not hold water. Water draining into the pond from adjacent lands should be free of silt. If it is not possible to locate the pond where there is a wide fringe of grass or woodlands bordering the edges, it would be desirable to create such a strip so that the silt will be deposited before it reaches the pond.

The cost of construction will increase as the height of the embankment or depth of the water increases. An embankment 10 feet high will require approximately three and one-half times as much dirt as one 5 feet high. Hence, it is well to limit the depth of water to some reasonable figure unless abundant funds are available for construction. Expense must be considered also when large streams are blocked, as additional spillway capacity and freeboard on the embankment will be required as insurance against failure of the dam during floods. The minimum depth at the drain structure should be from 6 to 8 feet. If a heavy demand is made on the pond for stock watering, then, it may be necessary to have deeper water, to carry both the fish and stock over protracted dry periods.

The pond area itself should be cleared of all trees, brush, shrubs, and debris. Leaf mold and other organic mulch act as a fertilizer and should be retained. It is not considered necessary to remove stumps but the yearly maintenance will often be decreased if they are removed from those portions of the pool where the water will be less than 3 feet deep at full pool. In locations where sprouts from stumps thrive, it is particularly desirable to remove the stumps from the shallow portions as they would soon choke up that part of the pond and both the fishing and appearance would be harmed.

Water less than 18 inches in depth has little value in the fish pond. By eliminating shallows it is possible to reduce the mosquito problem, increase the forage area for the fish, and it is easier to control aquatic vegetation. These portions should be excavated and the soil deposited uniformly along the shore line, care being taken to spread it so that the normal surface drainage into the pond is not blocked. It may be desirable, also, to use some of the top-soil thus obtained in surfacing the slopes of the embankment.

WATER CONTROL STRUCTURES

In order to manage the pond properly it is necessary to provide some means for completely draining the pool. This can be done by building a drain structure, with additional attachments for controlling the elevation of the surface of the pond at the lowest point in the base of the embankment. Such a structure is useful in draining the pond when repairs are necessary, and for providing facilities for piping water to stock-watering tanks. When the source of water for the pond is constant, with no danger of flash floods, this structure can be made to serve as the overflow. The discharge opening should be large enough to permit the normal water flow to pass over it at a depth of less than 2 inches. Otherwise the pond will become depopulated by loss of fish through the discharge pipe. If excessive runoff occurs, it would be advisable to provide auxiliary spillways cut about 1 foot above the desired pond level around the end of the dam sloping no more than 3 inches per 100 feet, in earth, or as steep as desired, in rock. Sand is too erodible. The size of the outlet pipe should be determined by someone familiar with the requirements, but it should not be less than 6 inches.

DAM OR EARTH EMBANKMENT

The dam or earth embankment is used to stop the flow of surface water and for the creation of the pond. Careful selection of the site for the pond should include consideration of the location of the dam.

It is preferable to build it in a narrow part of the valley so that its length and height will be kept at a minimum without affecting the surface area or depth of the pond water. Primary consideration should, of course, be given to the pond site but some balance should be found between the pond acreage and the amount of embankment needed to create the pool. The larger the fill, the more expensive will be the pond.

The base of the fill should be on good soil, with care taken to avoid gravel beds or peaty formations. The foundation for the fill should be relatively impervious to water just as should the pond bottom.

The shape of the embankment will vary with the type of soil to be used but generally the slope will be about three feet in width for every foot in height. Sandy or similarly pervious soil should have a flatter slope, perhaps five feet in width to one in height. The top width should not be less than six feet and it can be wider to suit the needs of the owner. Often such fills are used as roadways, in which case the top should be at least eight feet wide. The top of the dam should be not less than 3 feet above the desired elevation for the pool water (free board). In places where there is excessive flash runoff or high winds which cause large waves, additional freeboard may be advisable.

There should be a good bond between the embankment and the natural ground so that no seepage places exist. To insure this, it is necessary to remove all stumps, roots over two inches in diameter, vegetable matter, trash, logs, peat, etc., from the base before any fill material is moved into place. If the foundation material is found to be pervious after the removal of these materials, it is advisable to excavate a trench along the center line of the dam down to impervious soil or rock and to backfill with clay. Should rock outcrops exist, it may be necessary to pour a concrete cutoff wall into the rock and extending a few feet into the fill. After the entire base is cleaned, it should be plowed or otherwise scarified before placing the earth fill so there will be no unbroken division between the ground and fill.

The method of placing the fill material will vary with the type of equipment used. If a dragline or similar machine is used, the fill can be built without compaction, but adequate allowance should be made for settling. An average allowance would be one additional foot in height for every 5 feet of final dam height; i.e., if the final dam is to be 10 feet high, it should be built to 12 feet. All dirt should be placed as nearly as possible in its final position so rehandling will not be necessary. The slopes, too, should be built on the designed ratio, which, if 3:1, would mean a rise of 1 foot for each 3 feet of horizontal measurement. As an example, if the dam is to have a final height of 10 feet, it would be necessary to start the slope out 30 feet in order to reach the designed height at the right place. If it is planned to have a 6 foot, top width, the outside point for the dirt would fall 33 feet from the center line of the dam.

CARP

There are two aims in the establishment of a carp farm. (1) to breed fish ready for market by their third summer and (2) to produce breeding trios of this quick-growing strain for own use or for sale to other fish culturists. For carp one always uses trios for parent fish--one female and two males. The female should be at least four years old, because the ova or hard roe ripens at four years. The milt or soft roe of the male ripens in the third year. There should be anything from two hundred thousand to seven hundred thousand eggs from a female, depending on conditions of temperature, weather, water, food. At established carp farms they figure on an average of at least half a million eggs per spawner.

There are several varieties of the common carp. Cyprinus Carpio is the name of this species. It will breed anywhere, regardless of climate and latitude. The variety, most favoured by carp farmers and the trade, is the fish called the King Carp, which has been bred for a great many years from selected parents. Environment and different feeding has made it deep-bodied or fat-bellied or with longer body than the ordinary carp.

Other varieties which the carp farmer should find worth cultivating are the Mirror Carp and the Leather Carp. The Mirror Carp is a very handsome and showy fish; most suitable for a fair-sized garden pond. It is also good fish for the food markets. The aim of the carp farmer lies, mainly, toward the food market. To this end the better fish are those with a length only twice their breadth. Both Mirror and Leather Carp are European varieties.

The carp family, so far as pond culture is concerned, in addition to those mentioned, are the Crucian; the Grass; the Black; the Silver; the Bighead; and the Mud. The last five are Chinese. The Crucian should be avoided. It is a nuisance, too bony for food markets and a terrific breeder. The Bighead and the Mud carp would also be useless here. While it would be difficult to import breeding trios of the Grass carp from the Far East, it may be possible to secure eyed-ova.

THE SPAWNING PERIOD

The parent fish are in cool ponds while the spawning pond is getting warm. When the temperature of the latter has reached, either naturally or by artificial means, from sixty degrees to seventy-five degrees--the higher the better--the parent fish are removed from the cool pond to the warm one. This should be during the last week in May or the first week in June. Spawning will take place almost immediately. Fecundation takes place outside the fish's body. Sexual organs of the female are represented by two rolls of ova, which join each other between the vent and the spine, and when ripe, occupy the largest part of the fish's abdominal cavity. As the male fish chase the female she dashes towards the bunches of twigs and leaves in the pond--or other flora which may be growing there--and swimming slowly over these she releases a stream of ova, a few seconds later another stream. In fact, there are a score or more ejections within an hour. This may continue for the whole morning and sometimes go on into the afternoon. The male fish follow the spawning and, hovering over the spot, impregnate the eggs with their milt. This has a milky appearance and curdles like milk, but is composed of microscopic spermatozoa. So quick is the follow up of the males that the eggs are impregnated as they reach the water. As may be expected very many eggs fall in the water impregnated and are lost in the mud or eaten by the parents or some pond intruder. With the impregnation of the egg the development of the embryo begins.

It is generally agreed that 10 per cent of a usual spawn can be expected to hatch into fry. A spawn of half a million eggs should, therefore, result in fifty thousand fry. The eggs include in their content a yolk which serves a double purpose. One part assists in the development of the embryo and the other remains in the yolk sac which attaches itself to the belly of the embryo and supplies it with food for the first few days. It is interesting to observe how quickly the body grows. You first recognise the head and the spine. The eyes are particularly prominent. Then the heart and the blood vessels begin to act. In six to ten days, earlier if the water is very warm, the shell is broken and the fry emerges. It is transparent, extremely delicate, and has to remain quietly existing on the remains of the yolk in the sac for another day or two. By the time this is exhausted the fry has grown much larger and much stronger. It has, moreover, got the suction and digestive organs working and is now able to move in the water and feed itself. This is a very important moment in the life of fry. There must be ample food in the pond and this food can only be microscopic fauna.

REMOVAL OF PARENT FISH

Regarding the parent fish; they must be removed from the spawning pond after the spawning, otherwise they may feast upon the ova. After netting the female, she should be examined to see whether there is still ova in the abdomen. If so, this should be gently pressed out as in artificial propagation.

The young fish on removal into the fry pond should continue to be fed on the microscopic fauna for a day or two. Then gradually, as the days lengthen, minute organisms should be introduced into the pond and by July these organisms can be big enough to be seen with the naked eyes.

CARP NOT VEGETARIAN

Many mistatements have been made in the past by mistaken scientists about the carp's habits. The carp, except the Grass, is carnivorous. But he does not chew or masticate meat, nor vegetable matter, because he cannot. The carp's mouth is loose. He sucks in food. His snout has a pump-like suction arrangement. His masticating organs are insufficient for chewing anything before swallowing it. The carp is a bottom feeder, much like the tench. On the upper lip are two to four barbels which serve as feelers searching on the bottom. But he is not a scavenger. He dislikes and avoids any decayed or decaying matter.

If food in a pond is plentiful the fry will grow rapidly. On finishing the yolk sac they should be about half an inch long. A week or a fortnight later, on being transferred to a fry pond, they would be an inch or more. In a month's time the size should be two to three inches. This is the time to start sorting. Keep the smaller ones in their original fry pond and send the larger ones to other fry ponds. Until they reach the three-inch size the fry need careful handling. They are still extremely delicate, and netting and sorting into sizes disturbs them, and rough handling would kill them. The expectation, under normal conditions, is a loss of 25 per cent of fry from each hatch. But with care, fair weather and avoidance of haste, the loss may be reduced to a minimum. The rate of growth of the fry can be regulated by increasing or decreasing their number in a definite area of fertile ponds. A fertile pond is one that possesses large and continuous growth of plankton--the food of the fry. Continental records show that, after sorting, the larger fry, transferred to a separate pond, reached ten inches in length and one and a quarter pounds in weight during the following six months.

THE GRASS CARP

The habits of the Grass Carp are interesting because of its herbivorous nature. Even though it will take any kind of food that comes its way at random it prefers green grass and vegetables to any food of animal origin. All kinds of freshly-cut land grasses, weeds--if not too tough--leaves of some trees and all kinds of fresh vegetables are placed in a twenty-foot square frame in the pond. The frame is to prevent the grass, etc., from floating all over the pond. The Grass Carp, after the experience of a day or two, will come to this frame punctually for the food. During severe weather when green stuff may be difficult to procure foods like rice-bran and bean-meal are given. When well fed the growth of this fish is remarkable. Fry, at the end of the year in which they were hatched, commonly attain a length of six to ten inches and a weight of half to one pound. Some reach one foot in length with weight of one and a half pounds. If this size fish continues to grow it attains a length of two feet and four to five pounds weight in the second year. It is not unusual for a Grass Carp of four years of age to weigh more than ten pounds. Weights of twenty and thirty pounds are quite common, and sometimes there is a fifty-pound Grass Carp in the market.

The Black Carp is a snail feeder and must be plentifully supplied with snails. It is a small feeder on other foods, but with a generous diet of snails it grows very fast, in a pond, attaining ten pounds weight in three years.

The Silver Carp is a plankton feeder. Due to the fine structure of its gill rakers it can feed on big particles as well as small ones suspended in the water. The silver carp reaches maturity early and weighing from three to four pounds in the third year bears ripe ova or sperm.

These three species can be stripped and artificially propagated. They are, particularly the Grass Carp, widely distributed from Siberia to south China and should stand up to climatic conditions at almost any latitude and altitude. The fry of these species thrive on plankton. Duckweed, however, is considered the best food for fry of the grass carp. Unfortunately, duckweed grows rapidly in a well-fertilized pond, so much so that the fry cannot eat it quickly enough to stay its progress. This is an undesirable contingency, and as the weed becomes thick it must be cut and removed to give the nursery pond better light and ventilation.

CARP ARE LAZY, NOT SCAVENGERS

The carp is a lazy, luxury-loving fish. A placid pond with the right kind of shade-giving plants and, above all, plenty of food, makes for full enjoyment of its life. The carp has no work to do except suck in food. It would never do the housework in the pond. The accusation that the carp is a scavenger may be due to the cleanliness of carp ponds. This work is undoubtedly done by the snails, who are scavengers. Carp are fond of snails but, as already shown, can only eat them in the state of infancy when the shells of the snails are just forming and are soft. As the snail gets its hard shell the carp has, perforce, to ignore it. The consequence is that the pond is thus amply supplied with 'cleaners'.

Again, the statement that carp eats vegetable matter is, no doubt, due to the fact that the fish can be seen nibbling away among the pond flora. But it is really nibbling at the host of tiny crustaceans and other minute organisms who make their home on the leaves and stems of the plants. The grass carp, however, is primarily a vegetarian.

The manuring of ponds with animal excreta, poultry droppings and night soil may sound disgusting to the uninitiated, but the fish do not feed on these dungs except sometimes at first out of ignorance and curiosity. They avoid the small piles made, at intervals of days, here and there in the ponds. The piles disappear very quickly, due to water action, and in their place appear swarms of infusoria and plankton, especially minute crustaceans.

A carp farm does not require a hatchery house. The culture of carp and goldfish is very similar, any informational source which gives all necessary details for the cult of the goldfish should be followed by the carp farmer. Instead of leaving the impregnated ova in the spawning ponds they can be hatched, like goldfish ova, in special aquaria or wooden tanks. In the case of a smallish establishment with only a few ponds, such hatching is advisable. From the aquaria the fry will, in due course, be removed to the fry pond.

SECRET OF GROWTH

The secret of growth lies in the operative word 'plenty'. The fish, more particularly after they are removed from the nursery pond to the rearing and growing ponds, must have plenty of water, plenty of food and plenty of water-plants. The smaller ponds are the better; they must have plenty of earth on the bottom and plenty of manure. There lies the secret of fertility.

Manures should be, preferably, of animal or other organic substances. Vegetable compost also might be useful. All manures, before being put into a pond, should be thoroughly rotted. To get them into such suitable condition the manures brought to the pondside should be limed. Each forkful, as the heaps are being made, should be dusted with lime; then a good sprinkling of lime on the top. Finally, cover the heap with earth, well patted down. While waiting the week or two for the proper rotting one can use a guano manure. The Peruvian guano is practically impossible to procure, but a guano made from poultry manure is being produced in poultry raising areas. It is rich in nitrogen and comes in pulverized form. Before putting this in a pond it should be soaked for twenty-four hours in a container. The amounts to be used in the pond are twenty pounds (dry) per one hundred gallons of water. Over-fertility in a pond is not good for the fish, so care must be taken not to use too much manure at a time.

FIRM POND BOTTOM NECESSARY

A pond becomes fertile after manuring in that organisms are created and immediately find homes in the mud bottom or on the plant life. It is here that the carp feeds--on the bottom and among the plant life. As carp feed by sucking in their food they naturally get some earth and vegetable matter with the insects, worms or general crustaceans. This matter is not much benefit to the fish, but it is not harmful until the pond bottom becomes too slimy. With loose slime the carp sucks up more of it than of food, and it is not only indigestible to the fish but harmful to the small fauna living in the bottom. A firm, not loose, pond bottom is desirable and necessary. That is why each season carp ponds are emptied and allowed to go dry for a period. The slime can then be scraped out and a firm bottom re-established. When empty the bottom of the pond should be ridged throughout for a time. The furrows and ridges dry quicker than if the bottom is left flat.

For some hundreds of years carp farms have existed on the Continent. German scientists, some years ago, made researches into the food for carp in Europe. For ten years they examined carp stomachs from many localities under the microscope. They found that the best natural food of the carp is the small water fauna which has no hard or tough shell. With the gullet tooth of the carp the soft shell is broken and the contents swallowed without any addition of inorganic or vegetable matter. Worms and spiders are not in favour for the carp's diet, although they will be present in the pond. Water fleas and mites and all soft-shelled crustaceans are the carp's principal choice. It needs many good mouthfuls of these minute creatures, but the water fleas must help considerably, for a famous naturalist has stated that the issue of a single water flea in two months is three thousand millions. In a lifetime of a single female it is estimated her progeny would reach the enormous number of four and a half billions and weigh eight tons. These daphnia varieties often form a mass in the water and the carp sucks in the lot at one go. Most gnats and caddis fly are also favourite food for carp.

In ponds which do not become properly fertilized they can be colonized by removing some of the natural food from an over-fertile pond and introducing it into the under-fertilized ones.

HOME INDUSTRIES

HAND FORGING

Forging tools usually have wooden handles and are held in the hand while being struck with either sledge or mechanical hammers. Fig. 1 shows a group of commonly used hand forging tools. A illustrates the common ball-peen hammer, which is best suited to practically all of the hand forging operations. B shows the cross-peen sledge, and C shows the double-faced sledge. The sledges are the heavier hammers used by the hand forger's helper, and they vary in weight from 5 to 20 pounds. D shows the blacksmith's anvil, an implement that has been used in practically the same shape and form for many centuries. Occasionally, anvils of special shapes are designed and may be used for hand forging operations, but their application is fundamentally the same as that of the common-type anvil, which can be adapted to practically any hand forging operation. The anvil shown at D consists of a body a usually made from wrought iron to which a hardened steel top or face is welded. The portion which is designated b at the right is the horn, and the portion at the left designated c is the tail of the anvil. The base and feet upon which the anvil rests are at the bottom. There are two holes at the tail portion of the anvil. One is square and called the hardie hole; the other is round and is called the spud hole.

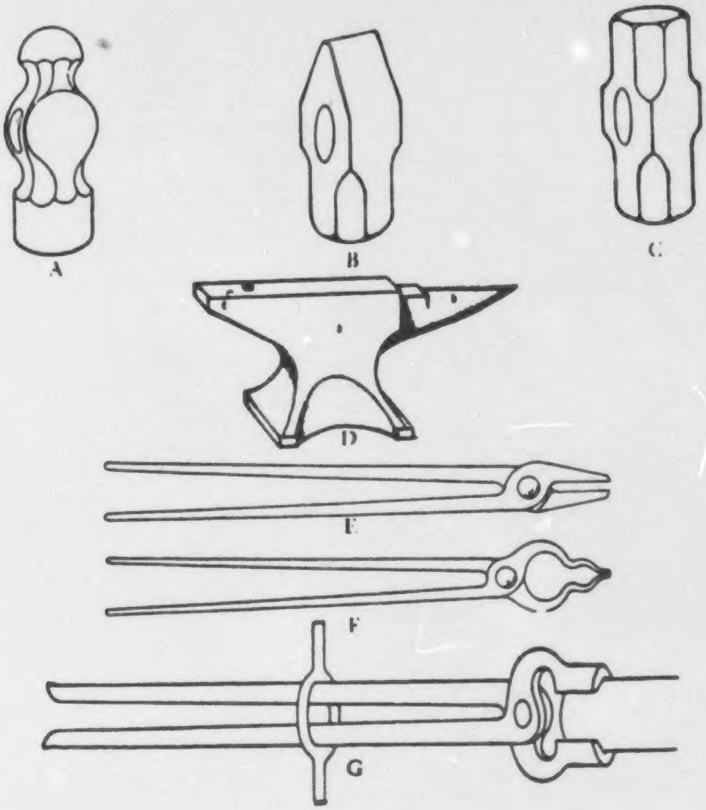


Fig. 1. Common Hand Forging Tools

Tongs of various shapes are very useful in hand-forging operations. Frequently parts to be hammered on the anvil cannot be held with the hands, but with the aid of suitable tongs these parts may be very conveniently manipulated. Small work, such as wires, and large work, such as ingots and bars, can be handled by properly designed tongs to suit each case. The jaws of the tongs are designed to grasp the parts to be handled and hammered on the anvil. A variety of tongs commonly used in hand forging is shown in Fig. 1. At E, flat-jawed tongs are shown; F shows pick-up tongs; G illustrates the link for clamping tongs on heavy work. These are only a few of the common-type tongs. There are numerous other tongs designed for the purpose of meeting whatever requirements may arise when forging needed parts and tools of assorted weights and shapes.

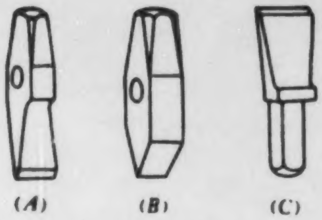


Fig. 2. Chisels

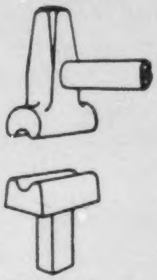


Fig. 3. Swages for Round Work

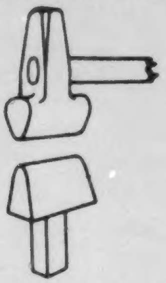


Fig. 4. Fullers

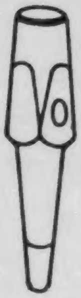


Fig. 7. Round Punch

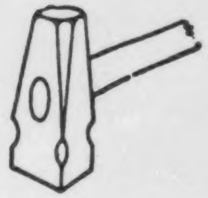


Fig. 5. Set Hammer

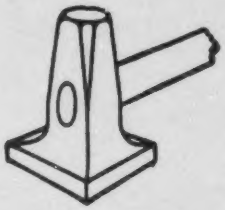


Fig. 6. Flatter

Other hand tools include various chisels which are used to cut off hot steel or to notch cold steel. Fig. 2 shows a set of chisels which are used for cutting off steel: A is the hot chisel, B is the cold chisel, and C is the hardie. The hardie is used by placing it in the square hole in the heel of the anvil, and striking the steel with the face of a hammer while resting the steel in contact with the cutting edge of the hardie. Swages of various forms are used for forming and finishing convex surfaces, round holes, and other shapes. Fig. 3 shows a set of swaging tools designed to shape round work. The upper tool is known as the top swage and is provided with a handle similar to a hammer handle. This tool applies the force upon the heated metal which is held on the lower swaging tool. This lower tool, known as the bottom swage, is held in place by a square stem or shank which extends downward and fits into the hardie hole in the tail of the anvil (shown in Fig. 1). Tools having hardie-hole stems should never be used on an anvil if they are so tight-fitting that it is necessary to drive them into place. Fullers are tools used for forming grooves or hollows while hot metals are being hammered into required shapes. Fig. 4 shows a set of fullering tools designed for working grooves or hollows into shape. A set consists of a top tool and a bottom tool. The top tool is provided with a handle and is used for finishing metal at round corners, around bosses, and on the inside of angles. The bottom tool has a square shank, which fits into the square hole of the anvil. Use fuller to spread metal in one direction only.

Various tools are designed for smoothing off flat work in the finishing process. These tools are known as set hammers and flatters. The set hammers are useful for working hot metal and forcing it into corners and narrow places. The flatters are designed for working wide, flat surfaces. Round punches are employed for punching round holes in hot steel. Appropriate punches of other various shapes are used for punching holes of oval outline, square outline, etc. Fig. 5 shows a set hammer. Fig. 6 shows a flatter. Fig. 7 shows a round punch.

The Blacksmith's Forge. The simplest forge or furnace used by the blacksmith is an open hearth with forced draft. In it iron, steel, or other metals can be heated and made ready for hammering into desired shapes. Refractory material, such as firebrick, is commonly used to build this type of forge, which is usually of rectangular shape. A simple hood is provided at the top of the forge to catch smoke and convey it into the smokestack. A water tank made of iron is often fastened to the side of the forge; this tank is chiefly used by the blacksmith for quenching a heated, steel tool in order to harden it. The blast (forced air) for these forges may be supplied by blowers or by hand power. An opening (tuyere) is arranged at the bottom of the forge, and this opening admits air under the fire; it can be regulated by a suitable valve arrangement.

Blacksmith's forges are made in numerous shapes and sizes, but all of them are built according to the same principles of construction --principles which are based on the fundamental purpose of a forge to contain the fire necessary for heating metal before hammering. A deep bed of coke should be maintained with a minimum amount of blast, via the tuyere, during the heating of steels in a blacksmith forge. A shallow bed of coke with a maximum amount of blast may be responsible for excessive oxidation (formation of scale) and possible burning (melting and sparkling) of the steel while it is being heated.

Fig. 8 shows a down-draft forge provided with a hood for carrying off smoke. A pipe is connected to the hood and extends downward, as shown at the left in the illustration, to an underground flue, which leads to an exhaust fan which draws out the air. This arrangement of underground piping is known as a down-draft system. The pipe furnishing the blast of air is also located underground; at the right in the illustration, a small pipe may be seen which connects with the underground blast pipe and leads upward to the tuyere. A simple valve arrangement, controlled by a handle, regulates the amount of blast admitted to the fire.

The air blast in some of the older-type forges is produced by bellows, whereas the more modern-type forges employ rotary fans, also known as centrifugal blowers, which may be hand-driven, the fans or blowers are operated by a belt from a pulley on the line shaft, or by a belt from an electric motor, or by a motor directly connected to the blower. The predominant fuel used in the blacksmith's forge for heating wrought iron and steel is a good quality of soft coal, free from sulphur, which is broken up into small lumps for best results. Coke is also a desirable fuel for heating iron and steel, because it does not tend to choke the fire in the forge. Charcoal is an excellent fuel, since it is free from sulphur and other undesirable impurities and gives a clean fire. Charcoal is especially recommended for heating carbon steels, but not for high-speed steels, because the temperatures developed from burning charcoal are not sufficiently high to properly heat the latter-type steels. Gas, oil, and powdered coal are also used as suitable fuels in the blacksmith forge for heating both iron and steel.

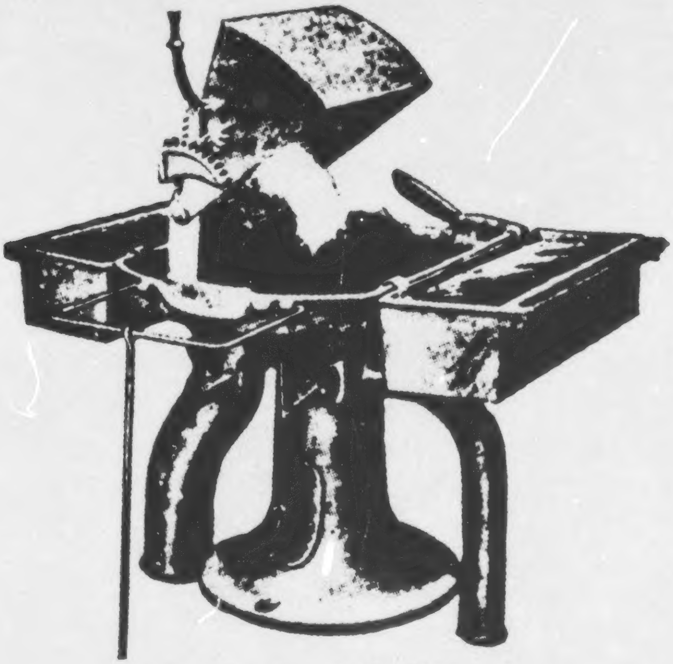


Fig. 8. Down-Draft Forge

Heating for Forging. The heating of a metal is one of the most important operations in the production of a forging. Frequently, this operation receives little attention, with the result that numerous difficulties are often encountered during the forging operation and during the heat treatments which usually follow forging. Many of the defects which seriously affect the behavior of the finished, forged piece are caused by improper heating of the metal prior to forging. Among the errors made in the heating of metal, overheating and nonuniform heating are the most prevalent.

The proper rate of heating the metal is such that no great difference in temperatures occurs between the surface and the center of the metal. When a metal whose surface is much hotter than its center is worked, a nonuniform effect of metal flow may result in internal bursting of the forging. Acdepted forging practice specifies approximately one or two hours per inch of section of a piece of metal, as a proper rate of heating. The time of soaking (equalizing the temperature) the metal at the maximum temperature should be long enough to insure uniform temperature throughout. A small steel bar may take only thirty minutes to be brought up to forging temperature and then only ten to fifteen minutes for soaking before forging. A very large steel ingot may take over eighty hours for heating and thirty hours for soaking.

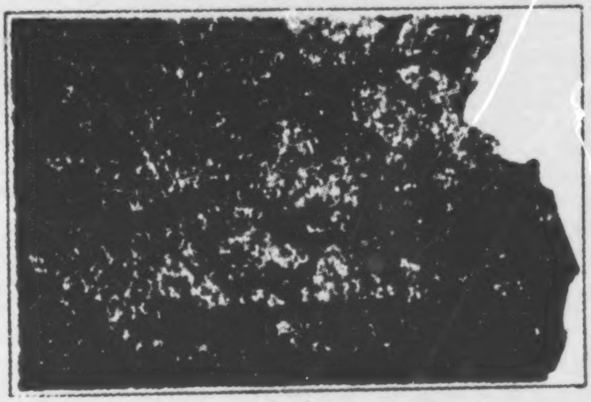


Fig. 9. Surface of a Section of a Burned Billet
Overheated in Forging

Forging Temperatures. Because of the ease of forging at high temperatures, there is a tendency to heat the work to much higher temperatures than those actually required for satisfactory forging.

Excessive temperatures may result in burning, which destroys the cohesion of the metal, as shown in Fig. 9. Remelting the metal is the only thing left to do when it is overheated and burnt. If the metal is heated to an excessive temperature but is not burnt, the high heating temperature will result in a high finishing temperature and coarse grain structure. The composition of the metal determines the beginning of burning and melting temperature ranges; the heating of the metal should stop short of these temperature ranges by at least 200° F. The amount of hot forging to be done will determine how

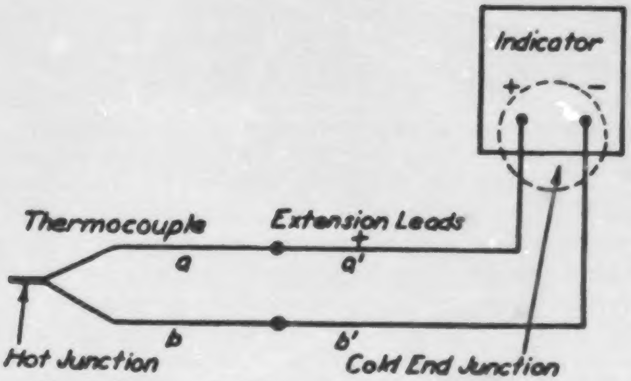


Fig. 10. Diagram of a Thermoelectric Circuit for Indicating Furnace Temperature

close to the burning temperature the metal should be heated. If considerable changing in shape is required to bring the raw material into finished form, the metal is heated to the limit short of burning or melting it. However, if only a slight amount of forging is necessary to form the metal, it should be heated just high enough, within the hot working range, to accomplish the finishing at the proper finishing temperature.

Measuring Temperatures. Numerous modern devices have been developed for measuring temperatures in furnaces where metal is heated preparatory to forging. A thermoelectric pyrometer system is most generally used for measuring the temperature of a furnace. The system consists of a thermocouple at the furnace, and a temperature measuring instrument that is connected to the thermocouple by wires. The measuring instrument may be the indicating type or the recording type or, in some cases, an instrument incorporating both features. Fig. 10 shows a diagram of a pyrometer circuit.

The thermocouple shown in Fig. 10 is a simple device made of two wires of different composition, which are welded together at one end and connected to the indicator at the other end. The welded end is placed in the furnace and forms the hot junction. The wires connected to the indicating instrument form the cold junction. The mere insertion of the hot end of the thermocouple in the furnace does not give a true temperature reading of the steel being heated in the furnace. Sufficient time must be allowed for the steel to heat up to the temperature of the furnace, and for the thermocouple hot-end junction to do the same, in order to obtain an instrument reading representing the true condition of the heated metal.

There are other satisfactory commercial types of pyrometers and temperature indicators. No matter what type of instruments are used, they should be frequently checked (about twice a week), if they are used continuously. Failure to periodically check the instruments may cause serious defects to become present in finished products.

There are some simple methods which have been used for many years to determine the temperature of heated metals, particularly iron and steel. These methods demand a trained eye to tell approximately the temperature of the metal under consideration. Of course, there is a possibility of error in a visual method of temperature identification, since no one can accurately determine the temperature of a heated metal by its color. Table I gives some idea of the color that metal is expected to be at different temperatures. A blacksmith hand forging a product has only one practical method of determining the temperature of the iron or steel heated in the coals of his fire--observation of the color of the metal. For exact forging temperatures of commonly used carbon and alloy steels, the student is referred to the Forging Handbook, published by The American Society for Metals of Cleveland, Ohio, 1939. The Aluminum Company of America and Reynolds Metals Company publish pamphlets in which detailed information is given regarding the exact forging temperatures of various aluminum alloys. For forging temperatures of other nonferrous alloys, the student is referred to pamphlets published by Revere Copper and Brass Incorporated, American Brass Company, and Dow Chemical Company. For detailed information regarding all properties of metals, the student is referred to the Metals Handbooks, published by the American Society for Metals of Cleveland, Ohio, 1948.

Color	Temperature (Deg. Fahr.)
Red, lowest visible in dark	878
Red, lowest visible in daylight	887
Red, dull	1100
Red, full	1370
Red, light (scaling heat)	1550
Orange, full	1650
Orange, light	1725
Yellow, full	1825
Yellow, light	1950

Simple Hand-Forging Operations. In all hand-forging operations, the metal should always be heated in the forge to a temperature as high as it will stand without injury. The most common hand-forging operation is the one of reducing the cross section of a piece of heated metal and thereby increasing its length. This is known as drawing out the heated metal--an operation which may be accomplished much faster by working the metal over the horn of the anvil than by hammering it on the anvil face. The metal will have a tendency to flatten out too much and spread over a larger area if hammered on the face rather than the horn of the anvil. In most cases, it is desirable to increase the length of the heated metal rather than its width; hence, the suitability of the horn portion of the anvil, which has a restricted area of action.

Fig. II illustrates the operation of drawing out the work over the horn of the anvil. It may be observed that the rounded horn acts as a blunt edge, which forces the metal to flow lengthwise when struck by the hammer. Drawing out the work over the horn utilizes practically the entire energy of the hammer blow in forcing the metal to stretch in the most advantageous direction. The hand tools called fullers, previously described, may accomplish to a certain degree the same results as the horn. In the operation of a steam hammer, a round bar of steel may be successfully employed for the same purpose.

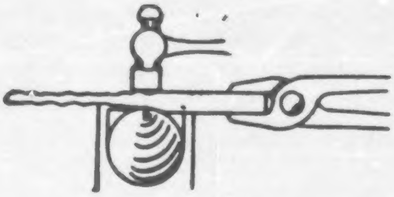


Fig. 11. Drawing Out Work over Horn of Anvil

The successive steps in drawing down a cylindrical bar of a given diameter to that of a smaller diameter are shown in Fig. 12. It may be seen in the figure that when drawing out or pointing cylindrical stock, it is best first to hammer it down square to the desired size, and then to round it to the required diameter by striking a few blows while the stock is still hot and plastic. A in the figure shows the original round size. B is the first step in hammering down the original shape to a square shape. This square shape is now hammered to an octagon shape as shown at C, and finally the rounding operation is shown at D.

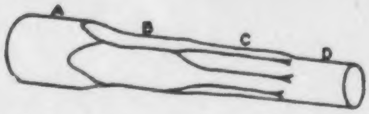


Fig. 12. Drawing Down Round Bar

Fig. 13 at A and B shows the improper and proper forging of round stock. If the preliminary round stock were hammered to the final round stock without intermediate squaring, the heated material would very likely split through the center under the blows of the hammer. The effect of the blows coming down upon the stock is illustrated at C by the arrows a. The metal is squeezed together in this direction and forced apart in the direction at right angles as indicated at C by the arrows b. The proper procedure of forging round stock is illustrated at D.

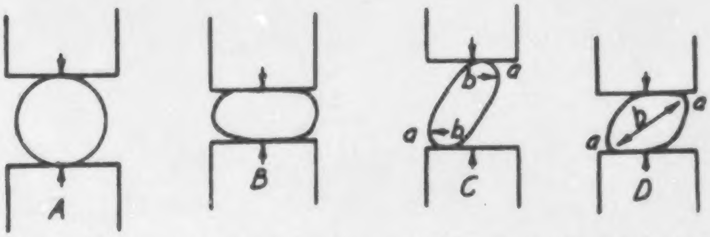


Fig. 13. Improper (*A*, *B*, C) and Proper (*D*) Forging of Round Stock

Another typical hand-forging operation is that of upsetting. This operation consists of working the heated metal in a way that its length is shortened and its thickness or width, or both, are increased. There are various methods used in upsetting heated metal. The most suitable method chiefly depends upon the size and shape of the work. When upsetting short pieces, the heated work is usually placed on one of its ends on the anvil and the upper end is then hammered directly down. If the work piece is not kept straight, there is a possibility of a bend or kink, and if any bend occurs, the metal must be straightened out before additional upsetting is carried out. When long pieces are to be upset, they are usually swung back and forth horizontally, and the upsetting is accomplished by ramming the end of the work against the anvil.

A forging operation known as swaging is employed when certain portions of the forged part are required to be smooth and accurate, or when cylindrical portions of the part are to be squeezed to assume an even, round, taper shape. If accuracy is not required, swaging can be done by hand with hand tools. For more accurate work and for larger sections, a pair of simple swaging forms or dies is attached, one to the anvil and the other to the ram of a steam or other power hammer. Fig. 14 illustrates a simple hot swaging operation with the aid of a pair of swaging dies. The dies shown at A and B have rounded corners, and this is a desirable feature, since the swaging will not form sharp corners in the heated metal as shown at D, which finally would be folded in as shown at E. The dies shown at C have correctly rounded corners, but the positioning of the work is not correct relative to the dies.

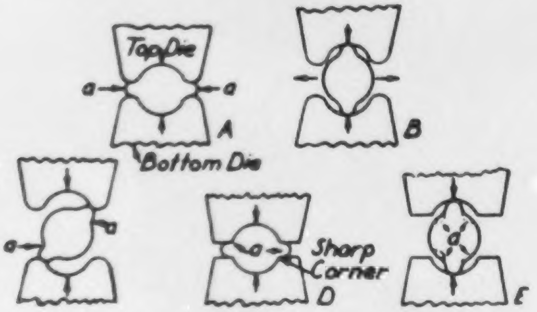


Fig. 14. Correct and Incorrect Dies and Methods of Swaging

In determining the amount of stock required to make a forged part of specific shape, any change in the density of the metal during a forging operation may be disregarded, since it is too small to consider for all practical purposes. Therefore, the volume of the metal before forging is essentially the same as that after forging, and it must be predetermined before the operation. Such volume may be computed by geometric principles.

Example. Suppose a 3-inch diameter steel bar is heated and forged by upsetting into a circular disk having a diameter of 8 inches and a thickness of 2 inches. What length of bar is required?

Solution. First, find the volume of the disk. The disk is really a cylinder, and the volume of a cylinder is found by multiplying the area of its base by its altitude. The base area is calculated by the formula $A = \pi r^2$ where A equals area, π equals 3.1416 and r^2 equals radius squared.

$A = 3.1416 \times 4^2$
$A = 3.1416 \times 16$
$A = 50.27$ square inches

The altitude (height) is 2 inches. Then $50.27 \times 2 = 100.54$ cubic inches, which is the volume of the disk.

Next, find the volume of a length of the rod 1 inch long.

The rod is also a cylinder and the same procedure can be followed in finding the volume of a piece 1 inch long.

$A = 3.1416 \times 1.5^2$ (radius is ½ of diameter)
$A = 3.1416 \times 2.25$
$A = 7.07$ square inches

The altitude of a length of the bar 1 inch long is 1 inch, because we think of this length as a cylinder having its base down. Then, $7.07 \times 1 = 7.07$ cubic inches.

Finally, if 100.54 is divided by 7.07 the result will be the number of inches of 3-inch bar necessary to form the disk. Thus, $100.54 \div 7.07 = 14.22$ inches. Call it 14.25 or 14¼ inches.

Exact reproductions of a given forging are seldom obtained in hand-forging operations because of a number of factors involved. The chief factor is that most hand-forging operations are carried out without the use of any dies. If dies are used in some cases, they are of a temporary nature and are designed simply and inexpensively without consideration of accuracy. Another factor contributing to size variations in hand forging is the frequent omission of proper allowances for certain conditions occurring in the forging operations. Whether forging by hand or by mechanical means, allowances must always be made for the shrinkage of the heated metal when cooling in open air after forging. Similarly, as the pattern maker allows for the contraction of the cold casting made from molten metal poured into a sand mold whose shape is fashioned by the pattern, the forger must also make allowances for the contraction of the hammered metal after it is cooled to the surrounding temperature. The rates of contraction of heated metals are given in handbooks.

Welding by Hand Forging. This is a simple process used in joining two pieces of metal by means of heating the metals to their forging temperature and then hammering them together. For centuries, this process was the only means used in welding metals, and it still is used to a limited degree at the present time when hand welding is sufficient to attain the required purpose. The chief requirement for a successful hand welding is the proper heating of the metals to be joined--this must be done cleanly and evenly throughout the metal areas in contact. An excessive temperature will cause the metal to burn. A sample of burnt steel is shown in Fig. 9. An insufficient heat will prevent the metals from sticking to each other. The experience of the welder, however, will dictate the proper temperature to which the metals should be heated before hammering. The color scale of iron and steel at different temperatures was shown earlier in this chapter. In the case of unknown conditions, it is recommended to experiment first with small samples of the metals to be joined before undertaking the main task of welding.

The metal areas in contact must be free from impurities, such as dirt, oxide scale, grease, and sand particles, before the welding operation takes place. When iron or steel are heated, their surfaces will oxidize very rapidly, i.e., an oxide scale will form on their surfaces due to contact with oxygen. This iron oxide or scale will prevent the heated areas in contact from successfully sticking and forging together. However, if the portions to be joined are heated to a temperature high enough to melt the surface scale, and if these metals are properly shaped at the joint, vigorous hammering will force out the molten scale from between the two parts that are to be joined. The result will be that only clean surfaces of the heated metals will be in contact and they will stick to each other.

Very high welding temperatures may be desirable for melting the surface scale but, at the same time, they may be the chief cause of burning the metals in contact. To remedy this latter condition, suitable fluxes are used in these forge-welding operations. Fluxes are used to lower the melting point of the scale. The operation is carried out by sprinkling flux on the metal surfaces to be joined immediately before the welding heat is attained. The metal thus treated is placed in the fire again, and is heated to the welding temperature. Then the metal is hammered to make the desired weld. The flux enables the scale to melt at a much lower temperature than would be the case if flux were not used. The applied flux melts immediately and spreads over the surface of the heated metal. It forms a protective shield which guards against the formation of additional scale by keeping out the oxidizing air. Fluxes serve only to lower the melting point of scale and to prevent air from contacting the heated work. It is an erroneous belief that flux also acts as a binder or cement which makes the two contacting areas stick together.

Various fluxes have been developed to suit the wide variation in forge-welding applications. The most common fluxes are sand and borax. When welding wrought iron or machine steel, sand is found to be a suitable flux. In the welding of tool steel or fine work, borax is the best flux, since it melts at a lower temperature than sand. This low-melting characteristic makes it possible to use lower welding temperatures--a desirable feature in the welding of high-grade work. A combination of borax and ammonium chloride (sal ammoniac) is also recommended as a satisfactory flux. The usual proportion of the component ingredients of this flux is 4 parts of borax to 1 part of sal ammoniac.

The proper shaping of the contacting surfaces previous to forge welding is known as scarfing. The ends of the pieces to be successfully welded are so shaped, or scarfed, that they do not fit tightly before welding, but just touch in the center of the joint, leaving the sides open. When the weld is made, the molten scale is forced from between the pieces. The welding method most commonly used to join flat bars together is lap welding. The ends of the pieces are scarfed by upsetting in such a way that they are much thicker than the rest of the pieces. The purpose of this shaping is, first, to allow for the metal which may burn off and become lost because of excessive scaling and, secondly, to allow for the vigorous hammering that causes the pieces to join together. Fig. 15 illustrates the proper shape of the ends and their overlapping position previous to their being joined by hammering.

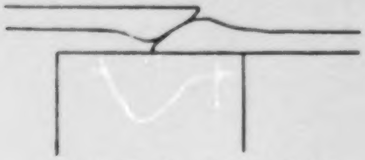


Fig. 15. Overlapping for Weld

When welding tool steel, an operator must exercise great care in heating the metal previous to working. The ends are scarfed in the same manner as other metals. A borax and sal ammoniac flux is recommended in welding tool steel. In some cases dissimilar metals may also be successfully welded, such as carbon, tool steel or alloy, tool steel to wrought iron or to low-carbon steel. The latter two metals are inexpensive as compared to the first two metals. In the manufacture of certain tools and implements, inexpensive metal may be made to serve as the backing or support, whereas more expensive metal may be needed for the tools' sharp edges or facings, which must resist wear and abrasion in service. Fig. 16 illustrates how welding of dissimilar metals is adapted in the manufacture of a machine knife. The support or back strip for the knife, shown at A, may be made from

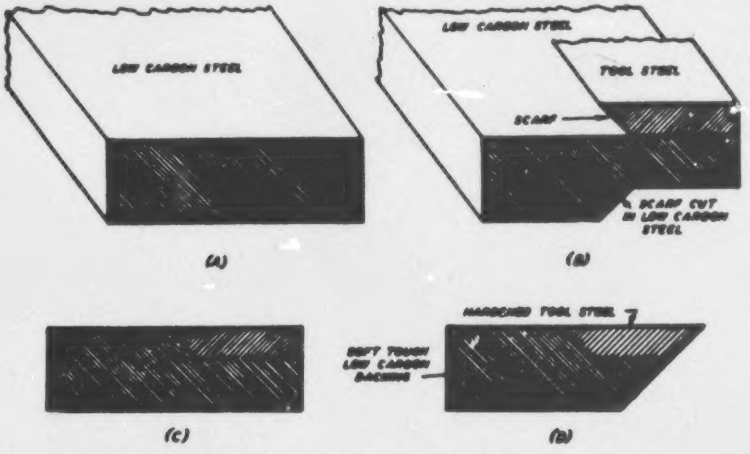

LOW CARBON STEEL
LOW CARBON STEEL
TOOL STEEL
SCARF
SCARF CUT IN LOW CARBON STEEL
(A)
(B)
HARDENED TOOL STEEL
SOFT TOUGH LOW CARBON BACKING
(C)
(D)

Fig. 16. Welding in the Manufacture of a Machine Knife

from inexpensive low-carbon steel. The support is shaped or scarfed at a 45 degree angle to make a suitable joint with the tool steel, which is also scarfed at the same angle. This is illustrated at B in the figure, where both members are shown ready for the weld. A section of assembled parts after hammer welding is shown at C. The finished knife after grinding is shown in section at D.

Welding of dissimilar metals is common in the manufacture of numerous, edged tools used in various industries--tools such as knives, blades, chisels, and others. There are definate advantages derived from this practice. The cost of the product is reduced at no sacrifice of its quality. Usually, only the working portion of the tool is heat treated; the soft backing allows for straightening after the heat treatment. The soft backing also insures a much stronger finished tool. Another illustration of hammer welding of an expensive, tool-steel blade to an inexpensive low-carbon-steel holder or ferrule is shown in Fig. 17.

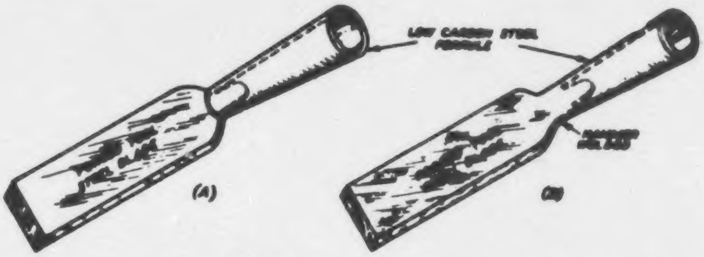

LOW CARBON STEEL FERRULE
(A)
(B)

Fig. 17. Hammer-Welded Blade and Ferrule of Wood-Working Chisel

Tool Forging by Hand. Numerous tools, such as lathes, shapers, and planers--various chisels for work on metal, stone, and other materials--tools used in the cutting and carving of wood, are in most cases hand forged by hammering to desired shapes. Afterward, they are rough ground, hardened, tempered and, finally, ground to the exact shape and required keenness. The methods used in hand forging these tools are essentially the same as those previously described.. The proper heating of the stock in the furnace before hammering is an important prerequisite for successful forging. Correct temperatures of the furnace and of the metal, both at the beginning of forging process and at the end, proper handling of the equipment, etc., are observed with greater exactness in making keen-edged tools than in forging ordinary products.

Many grades of steel, both plain carbon and alloy, are employed in the making of tools by hand forging. For economy reasons, plain-carbon tools are satisfactory if the tools are employed in light service and are not subjected to the influence of high temperatures, high speeds, and other conditions detrimental to this type of material. The carbon content is usually high, 0.90 per cent for chisels and about 1.20 per cent for cutting tools on machines, such as lathes, shapers, and planers. In the forging of a chisel, the steel stock is first heated in a suitable forge or furnace to a good yellow heat and then is hammered into the required shape and finished smoothly before the metal cools off appreciably. Since the equipment to hand forge a tool consists only of an anvil (particularly the horn) and hammers, as shown in Fig. 18, skill in heating the stock and holding it over the anvil properly is required. An experienced craftsman--one familiar with the behavior of heated metal--is usually called upon to carry out the operation, especially if high-grade, expensive tools are to be hammered to shape. Fig. 18 illustrates the method and steps followed in hand forging a cape chisel.

The completed tool is shown at the top of Fig. 18. The first step consists of hammering a portion of the stock over the anvil horn, as shown at A. Other portions of the work are, then, progressively hammered on the wider surface of the anvil as shown at B, C, and D.

Fig. 19 shows the method of forging a typical cutting-off tool. The hammering of the thin portion of the tool over the anvil is shown at A. The position of the hammer relative to the work should be noted in the illustration. The completed tool is shown at B.

Fig. 20 shows the method and steps used in making the general shape of a diamond-point tool. The shape is started by using a bottom fuller, working the stock down about one-third, as shown at A. The rounded edge of the anvil may also be used in place of the fuller. The point is formed then, as shown at B, and turned on the side, as shown at C, for starting the diamond shape. Both sides of the tool are worked until the proper shape and size are formed as desired. Finally, the tool point is placed on the flat side on the anvil, and with the aid of a hot chisel, the point is cut to proper length, as shown at D.

Fig. 21 shows the method of forging a side tool. The operation is started by drawing down a point endwise, as shown at A in the illustration. The point is hammered out at the corner of the anvil so that it can be drawn small without striking the corner of the hammer into the anvil. The work is then brought to the flat horn of the anvil for sharpening or drawing out thin on one side. At B is shown how part of the face of the hammer is extended over the edge of the anvil so that all of the recess in the work will occur on the side that is

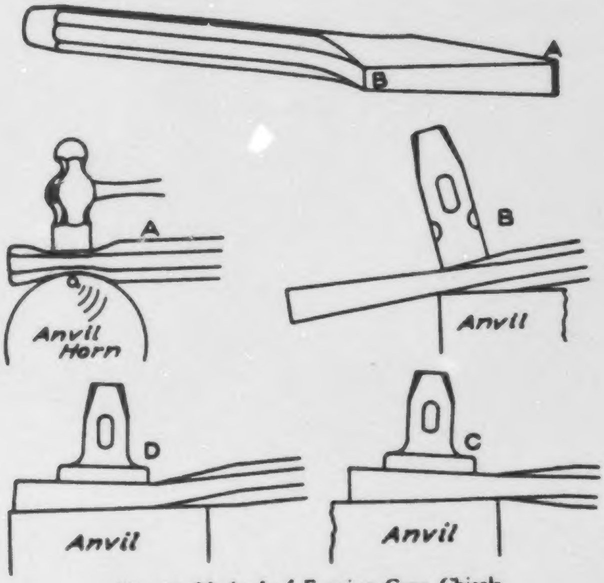


Fig. 18. Method of Forging Cape Chisels

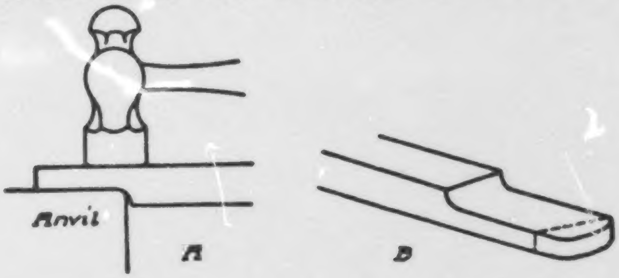


Fig. 19. Method of Forging a Cutting-Off Tool

down. Next, the tool is placed on the anvil as shown at C, and its top edge is bent over to get the proper side-clearance, as shown at E. D shows how the completely forged tool is quenched in a cold liquid, water or oil, after heating it to the hardening temperature. This temperature may be recognized by the color of the heated tool. It varies from a full red to a light red. The color scale of steel was shown earlier. The heating of the tool and the rapid quenching hardens the metal. After hardening, the tool is reheated to a lower temperature than that of hardening, and then is cooled to room temperature. This last operation tempers or draws the metal, i.e., it reduces the hardness but increases the toughness of the tool. Tempering temperatures vary, depending upon the degree of tempering or drawing that it is desired to achieve in a product. Such temperature may be as low as 400 degrees F. or as high as 1200 degrees F., or even higher.

Of course, production tools used in large quantities are forged by means of power hammers and precise dies. The accuracy of the tool shape is assured by the workmanship of the dies. Forging dies are expensive, but their cost is warranted, since they are used in large volume production of required parts. High-production tools are made from material of superior quality--stock that will withstand high temperatures encountered in high-speed machining and that will resist wear, abrasion, and other detrimental effects.

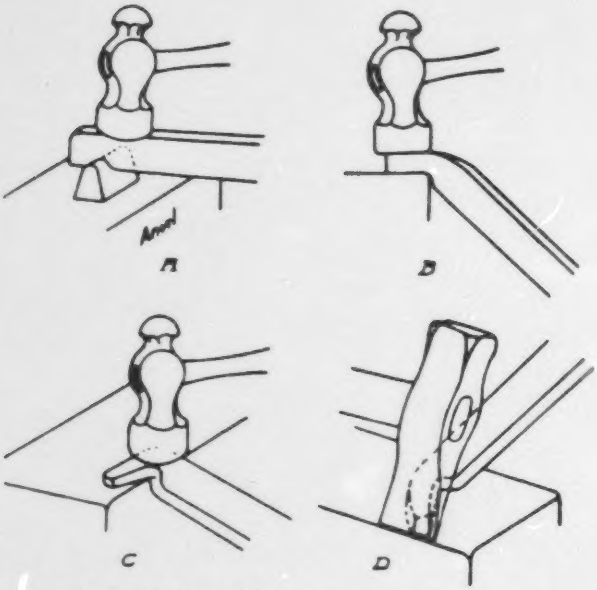


Fig. 20. Method of Forging a Diamond Point

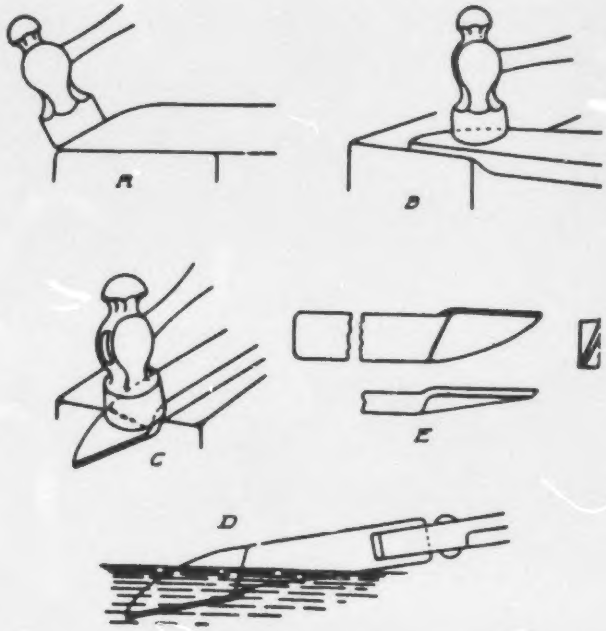


Fig. 21. Method of Forging and Hardening a Side Tool

SOAP

Soap has been used as a cleansing agent for more than 2,000 years. It is a good detergent when used in soft or softened water. It cleans well because it can be dissolved in warm or hot water to form suds which penetrate quickly and deeply into the fibers of a fabric; it emulsifies grease; and holds the dirt in suspension until it can be rinsed away. Making soap at home is a thrifty practice for any family. It's a way to use fat from butchering and cooking which is often wasted.

INGREDIENTS FOR SOAP

Only three ingredients are needed to make soap--cold water, lye, and fat. Six pounds of fat and one can of lye can be made into nine pounds of soap. Fat from butchering can be used to make an excellent quality soap. Used fat can be clarified to make clean fat suitable for soapmaking.

Lye

When you buy lye notice the sodium hydroxide content. Since there are many different brands on the market read the label and be sure the sodium hydroxide content is 94 to 98 per cent. It is usually sold in cans containing about 13 ounces.

ANTIDOTE FOR LYE -- LYE IS POISON -- IT BURNS

> For protection when making soap, keep a small bowl of vinegar near, so if you spatter lye on your hands you can dip them immediately into the vinegar to neutralize it. If burns are serious, call a doctor immediately. Drench burned spot as soon as possible with water and bathe with vinegar. If lye has been swallowed, give juice of lemon, orange, rhubarb or grapefruit, or if you don't have these use vinegar. Give as much as the person will take.

Fats

You can use any animal or vegetable fat but not mineral oil.

Mutton tallow has a very high melting point and is hardest of all animal fats. If will make a hard, dry soap unless additional water is added or it is mixed with soft fats as lard, goose grease or chicken fat.

Beef tallow is next in hardness and should be mixed with softer fat or have additional water added.

Poultry fat used alone makes a soft spongy bar, so should be used with harder fats.

Any of these fats can be mixed and will make good soap. Soap made from oils or soft fats requires less water and needs to dry longer than soap made from tallow.

Store fat in a cool dry place while collecting enough for soapmaking. However, it's best to make fat into soap promptly and let the soap age rather than to let the fat get old and rancid. Soap improves with age, but fat does not.

To Render Fat

1. Grind fat using the coarse blade or cut into small pieces.
2. Put into a large kettle on top of range or in roaster in the oven. Add a quart of water for each 10 pounds of fat.
3. Use moderate temperature and stir occasionally.
4. When cracklings begin to brown and settle, strain and squeeze all of the fat from the cracklings. Cracklings themselves don't make soap.

To Clarify Drippings and Remove Salt

1. Put drippings into kettle with equal amount of water.
2. Bring to a boil, remove from heat and stir. (Caution: fat boils over easily)
3. For each gallon of hot liquid pour 1 quart of cold water over the surface of the fat. (Caution: if fat spatters cool a little) Stir slightly.
4. Cool and skim fat from the surface.

To Remove Rancidity

1. Boil sour or rancid fat in a mixture of 5 parts of water to one part of vinegar.
2. Cool and skim fat from the surface.
3. Remelt the fat and for each gallon of hot liquid add one quart of cold water. Stir slightly.
4. Cool and skim fat from the surface.

Other Ingredients

If perfume is desired use oil of citronella, oil of sassafras, oil of lavender or oil of lemon.

Uncolored soap is usually most satisfactory. However, when making toilet soap if a slight yellow color or marbled effect is desired, use liquid butter coloring. Other colors are not easily available.

Pumice stone powder for mechanics' soap.

Oil of tar for tar soap.

Castor oil to prevent abrasive from settling.

Borax to quicken sudsing action.

Coconut oil to produce a fine sudsing soap.

Equipment Needed

Utensils should be iron, enamel, crockery or glass. You will need:

Large round bottom bowl or utensil (6 quarts)
Small bowl or utensil (2 quarts)
Standard tablespoon, cup and pint measures
Slotted wodden spoon
Dairy thermometer
Household scales
Flat wooden box soaked in water and lined with wet cotton cloth.

Making Soap

The "Saponification" Process

Making soap is a chemical process. When lye and fat are brought together under the right conditions, they react to make entirely different products. Fat plus lye produces soap and glycerine. This process is called spaonification. It may take several weeks for complete saponification to take place. When it is saponified, the product never separates into fat and lye again. In homemade soap, glycerine is left in. Commercially it is separated and sold as glycerine.

If proportions used are correct and saponification complete, the soap formed will be neutral. If any free lye is present, the soap "bites" when touched with the tongue.

Precautions

1. Don't use aluminum utensils for making soap.
2. For excellent soap use *exact* weights, measures and temperatures.
3. Always add the lye slowly to the water.
4. Always add the lye solution slowly to the melted fat.
5. Rapid addition of lye to fat or jerky, uneven stirring may cause separation.
6. Pour mixture into the mold carefully.
7. Don't allow new soap to freeze.

Correct Temperatures Are Important

The following chart gives temperatures for the lye solution and melted fat. Use lower range in warm weather.

Type of Fat	Temperature of Melted Fat	Temperature of Lye Solution
Tallow	120° F - 130° F	90° F - 95° F
Lard and tallow (half and half)	100° F - 110° F	80° F - 85° F
Sweet lard or other soft fats	80° F - 85° F	70° F - 75° F
Soft rancid fat	97° F - 100° F	75° F - 80° F

Recipes for Cold Process

Soap with Soft Fat

5 cups cold soft water
1 can lye (13 oz.)
6 pounds soft fat (lard or mixed fats.)
2 tablespoons of borax may be added
1 to 2 tablespoons of perfume if desired.

Soap from Tallow

7 cups cold soft water
1 can lye (13 oz.)
6 pounds of mutton or beef tallow
2 tablespoons of borax may be added
1 to 2 tablespoons of perfume if desired.

Method

1. Put correct amount of cold water into a 2 quart utensil (earthenware or heatproof glass). Add slowly one can of lye and stir until disolved. Cool solution to temperature given in chart.

2. Put melted fat into a six quart utensil (earthenware or glass). Add the lye solution in a slow steady stream. Stir slowly until the mixture is thick and creamy.

3. If desired add any or all of the following: borax, perfume and color.

4. For bar soap pour carefully into a soaked wooden box lined with a wet cloth. When well set remove and cut into convenient sized cakes. Pile so air circulates around each cake.

5. For granular form leave in container and stir occasionally over a period of several hours, until it becomes dry and crumbly. You can also grind bar soap through a food chopper for granular form. If you prefer flakes, cut bar soap with a slaw cutter. Granular soap or flakes can be stored in a pasteboard box or any other convenient container.

Curing Soap

Best results are obtained if homemade soap is cured at room temperature. It can be used at the end of a month, but since aging improves it a longer period is better.

OTHER SOAPS

Toilet Soap is made like other soap, only the fat used is from butchering instead of drippings. It gives a whiter, better quality soap.

Floating soap is made by folding air into any soap when it begins to have a creamy consistency. Test for floating by dropping a few drops on cold water. Except for the convenience of soap staying on top of the water, floating soap is no better than other soaps.

Tar soap: As any plain lard or tallow soap becomes creamy, add eight ounces of oil of tar. Work in well by stirring to prevent small lumps from forming. Tar soap is used frequently for shampoo.

Shaving soap. To one-half recipe of soap add 3 ounces of coconut oil. Or use all lard for the fat.

Mechanic's Hand Soap (Makes 11 pounds)

3 pounds homemade soap
6 cups water (7 cups if the soap is very dry)
1 tablespoon borax
3 ounces light mineral oil
5 pounds of pumice stone powder

Method: Dissolve 3 pounds of homemade soap in 6 cups of water. Add borax and mineral oil. When cooled to a creamy consistency work in the pumice stone. Pour into wide mouth jars or cans which are then tightly covered and use as a paste, or pour into a mold and when hard cut into cakes.

IF YOU HAVE "BAD LUCK"

If soap separates, it can be reclaimed. Cut or shave soap into an enamel or iron kettle. Use rubber gloves or cut soap without touching. Be sure to use any lye that has separated out and about 2/3 pint of water for each pound of soap. Stir slowly and evenly and bring gradually to the boiling point. Watch carefully for it will boil over easily. Boil until the mixture drops from the spoon in sheets. Pour into molds and cover as before.

GOOD SOAP SHOULD . . .

Be neutral, no lye or fat present
Be attractive
Have a clean, wholesome odor
Curl when shaved (if fresh)

CANDLES

Candles are run in moulds. For this purpose melt together one quarter of a pound of white wax, one quarter of an ounce of camphor, two ounces of alum, and ten ounces of suet or mutton tallow. Soak the wicks in limewater and saltpetre, and when dry, fix them in the moulds and pour in the melted tallow. Let them remain one night to cool; then warm them a little to loosen them. Draw them out, and when hard, put them in a box in a dry, cool place.

To make dipped candles, cut the wicks of the right length, double them over rods, and twist them. They should first be dipped in limewater or vinegar and dried. Melt the tallow in a large kettle, filling it to the top with hot water when the tallow is melted. Put in wax and powdered alum to harden them. Keep the tallow hot over a portable furnace, and fill up the kettle with hot water as fast as the tallow is used up. Lay two long strips of narrow board, on which to hang the rods; and set flat pans under on the floor to catch the grease. Take several rods at once, and wet the wicks in the tallow; when cool, straighten and smooth them. Then dip them as fast as they cool until they become of the proper size. Plunge them obliquely, not perpendicularly; and when the bottoms are too large, hold them in the hot grease till a part melts off. Let them remain one night to cool; then cut off the bottoms and keep them in a cool, dry place. Cheap lights are made by dipping rushes in tallow.

CERAMICS

Ceramics, a term applied to all useful or ornamental clay objects that are baked. Ceramics includes both pottery and porcelain. Any clay object fashioned from earth and hardened by baking, either in the sun or by firing, is considered pottery. Porcelain is one particular kind of pottery. Translucent, vitreous, and basically white, true porcelain is formed from specific types of clay, rock, and quartz or quartz substitutes.

The making of pottery is an ancient art, antedating, in most cultures, the knowledge of metals or even of textiles. Porcelain, however, is a much later development, first appearing in China as late as A.D. 600, and in Europe, in the eighteenth century.

TECHNIQUES

Material. Clay is the basic material in the making of ceramics. When it is first dug from the earth, the clay is mixed with sand, small stones, decayed vegetable matter, and other foreign material, all of which has to be removed before the clay can be used. This is accomplished today, as it was in ancient times, by mixing water with the clay and letting the mixture stand in a large basin. The impurities fall to the bottom, and the upper layer of clay and water is pumped or bailed into an adjoining basin. The process is then repeated, sometimes several times, each succeeding settling purifying the clay still further until the desired quality is achieved.

The damp clay is stored indoors until needed. Storage of the clay for several months actually improves its working qualities. It allows the clay to take a "set" so that although remaining malleable, the clay will hold its shape while it is being molded. The fresh clay is often mixed with old clay from a previous mixed batch; this increases bacterial action and also seems to improve the quality of the material.

A piece molded in clay undergoes a certain amount of shrinkage, both while it is drying and during the firing process. To insure uniform drying and to minimize shrinkage, coarsely ground bits of fired terra cotta, usually broken pottery known as "grog," are added to the clay. The grog also increases the stiffness of the clay, thus reducing its tendency to slump while being modeled.

Forming the Pot. Freehand Technique. The earliest technique for making pottery, invented about 5,000 B.C., at the beginning of the Neolithic period, was the freehand forming of a vessel from a lump of clay. This was accomplished by pushing and pinching the clay until the desired shape was achieved. Examples of this early work have been found in Jordan, Iran, and Iraq. This technique is still used today by some potters.

Coil Technique. A later development was the coil technique, whereby the pot was built up from a number of strands of clay. A thick strand was coiled around a flat, hand-formed clay base and then pinched and smoothed to form a good joint. Additional strands were added until the pot reached the desired height and shape. To assist in the building and smoothing operation, a rounded stone was sometimes held inside the wall of the pot while the outside surface was beaten with a paddle. This technique produced very fine pottery with walls of uniform thickness. The coiled pottery method has been compared to the technique of basket weaving in which baskets are woven with long ropes of fiber, and it may be that the coiled pottery technique derived from basket making.

A refinement of the coil technique involved forming the pot on a small piece of rush matting or a curved potsherd (a fragment of a broken pot). The mat or potsherd acted as a base during the building of the pot and as a convenient pivot so that the vessel could be readily rotated between the hands of the potter. This manual rotation gave the potter an opportunity to continually smooth the pot and adjust its symmetry as he built it. Some primitive groups, such as the American Indians, never progressed beyond this technique, and all of their pottery was produced by this method. The coil method continued to be employed in the construction of very large storage jars even after the invention of the potter's wheel.

The Potter's Wheel. The invention of the potter's wheel occurred near the end of the fourth millennium B.C. Its use was not immediately widespread, some areas having adopted it far ahead of others. One of the first areas to use the wheel was Sumer, in ancient Babylonia, about 3250 B.C. In Egypt it was used as early as the latter part of the Second Dynasty, about 2800 B.C., and in Troy, wheel-made pottery was found at the Troy IIb level, about 2500 B.C.

The ancient potter's wheel was a heavy, sturdily built disk of wood or terra cotta. On the underside of the disk was a socket which fitted over a low fixed pivot. The entire wheel was balanced to run true without wobble or vibration. It was customary practice in Greece to have a boy, presumably an apprentice, turn the wheel by hand, adjusting the speed at the command of the potter. The large size and weight of the wheel provided ample momentum once the wheel was put in motion. Having an assistant for the labor of wheel-turning allowed the potter to use both hands in forming the vase and to devote his entire attention to it. The kick-wheel, or foot-operated wheel, apparently was not used until Roman times. In the seventeenth century the wheel was spun by means of a cord working over a pulley, and in the nineteenth century a steam-driven wheel was introduced.

The process of making a pot on a wheel starts with wedging the clay to remove air bubbles, to make it homogeneous, and to get it to the proper working consistency. A ball of clay is then centered on the rotating wheel and firmly held in cupped hands until it runs true without wobbling. Pressure of the thumb in the center of the ball of clay forms a thick-walled ring which is slowly pulled upward between the thumb and fingers, creating a cylinder. The cylinder can then be opened into a bowl shape, drawn up as a long tube, flattened into a plate, or closed to form a sphere, at the pleasure of the potter. This concludes the "throwing" operation, and the vase is set aside to harden. The following day, when the clay has dried leather-hard, the pot is centered upside down on the wheel. As the wheel rotates, metal, bone, or wooden tools are used to "turn," or refine, the shape by shaving off unwanted clay. The modeling of the pot is now finished and the pot is ready for decorating and firing. (The foot or other sections of the pot may be thrown and turned separately and then joined to the body of the pot with clay slip--liquid clay used by the potter as a cement.)

Casting. Casting is a technique used in making a series of identical pieces of pottery. First, a plaster mold is made from the piece to be reproduced. A liquid clay slip, called a casting slip, is then poured into the mold. It is allowed to remain there until the plaster absorbs the moisture of the clay slip near the surface of the mold, causing this layer to solidify. This takes about an hour. The mold is then inverted, and the remaining slip is poured out. After the thin-walled clay casting has hardened slightly, the mold is carefully opened and the casting removed. The hollow clay casting is retouched and finished by hand and subsequently fired.

In ancient times, the soft, pliable clay was pressed into the mold by hand. It was not poured, as it is in casting. The manufacturing procedure began with the forming of the original model. The patrix, or master model, was made from clay by a sculptor, keeping in mind the ultimate use of the vase and the intermediate manufacturing steps. In most of these so-called plastic vases, the mold-made section was joined to a part, usually the mouth, formed on the potter's wheel. Therefore, the patrix was made for only the molded section.

Firing. The technique of treating dried clay with heat to change it from a soft, fragile substance to a hard, vitreous material was discovered by man about 5000 B.C. The discovery was undoubtedly accidental, possibly as a result of building a campfire over a deposit of clay. When the fire burned itself out it was undoubtedly noticed that the clay underneath had become extremely hard. The inventive first potter must have repeated the phenomenon by shaping something from the soft clay and placing it in the fire. When this piece emerged from the firing intact and in a hard, permanent form, an industry was born.

Primitive methods. The early potters did not use a kiln; they arranged their dried clay vessels in a small pile and then covered them with whatever fuel was available, such as wood, charcoal, twigs, straw, or dried dung. Primitive groups in Africa and in both North and South America have continued this particular practice to the present day. Since the temperature is not uniform in a mound of pots and some of them do not reach the proper temperature for the vitrification of the clay, this type of firing produces uneven results and causes the loss of a substantial number of pots by breakage. When the unvitrified pots are filled with water they dissolve and revert back to soft clay. The color of this pottery is also rather unpredictable, as some areas of the fire are oxidizing in character and others are reducing. Therefore, some of the pottery is a brownish-red in color and some is grayish or black.

The Kiln. A kiln is a specially built chamber for firing pottery which allows the potter more control over the process than does an open fire. Usually the area for burning the fuel is separate from the area in which the pots are placed. Openings are provided for tending the fire, for the placement and removal of the ware, for observation of the firing, and for control of the flow of air through the kiln.

Procedure. Most pottery is fired twice. The first firing, done after the pot is formed, hardens the clay, producing what is known as "biscuit"; the second firing, done after the pot is glazed, fixes the glaze.

In the first stage of firing, the moisture in the clay is slowly removed. The firing is done slowly, to avoid cracking the ware. When the temperature reaches 1112°F., the clay is completely dehydrated. The clay is now red throughout and is brittle, porous, and absorbent. In the second firing, after glazing, the temperature reaches 1112°-1652°F. If the air is freely admitted to the kiln during this process, the clay is thus oxidized and all carbonaceous matter is removed. If the air is excluded from the kiln, the clay will be black and is said to be "reduced."

Decoration. There are three basic types of decoration: underglaze, inglaze, and overglaze. Glazes are smooth, glassy coatings made of mixtures of minerals such as lead, flint, borax, feldspar, or lime.

Underglaze. As the term implies, underglaze decorations are applied before the ware is covered with a transparent glaze. Colors are produced by the use of colored oxides of elements such as cobalt, nickel, chrome, manganese, and iron. The coloring oxides are mixed with materials which will fuse during subsequent heat treatment, thus adhering to the ware. Decoration is applied by hand painting, application of decalcommania, silk-screening, or spraying through other types of stencils. One method of decoration, called sgraffito, entails painting the entire piece with a clay slip of a different color than the original and then scratching the desired design through the coating. Underglaze decoration is extremely durable, being protected from wear and chemical attack by the covering glaze.

Inglaze. Inglazed decoration is merely the application of a solid-colored glaze to a piece. This method is very widely used. It is quite difficult to produce sharp images of any design within the glaze itself, because of the melting process and the diffusion which take place upon firing the glaze. However, a number of pleasing effects are produced by application of different colored glazes which flow together partially during the heat treatment.

Overglaze. In overglazing both colored-oxide media and materials which actually form deposits of a metal are applied over the glaze. Since overglazes are fired at relatively low temperatures (1300°-1600°F.), a great many coloring materials which would not be stable at the higher temperatures needed for the firing of underglazes can be used. Thus, overglaze decorations allow the use of the greatest palette of colors in ceramic work. Metallic decorations consist of either a metal salt or very finely divided metal particles suspended in a medium which produces a consistency suitable for painting or silk-screening onto the ware. During firing, the medium volatilizes, leaving the metal behind. If the coating is sufficiently thin the metal does not appear metallic but rather produces a mother-of-pearl type of luster. The color of this luster can be varied by the use of different metals. If the decorating medium is compounded to leave a somewhat thicker coating, the result will be a shiny metallic coating; gold, silver, and platinum are the metals normally used for this. The media containing powdered metal particles are usually applied quite thickly by silk-screening and thus produce the most durable metallic decoration. These materials are dull rather than shiny after firing and must be burnished.

CHARCOAL

Charcoal is the black porous brittle material consisting mainly of carbon that remains after burning vegetable and animal matter with limited access of air. The term is popularly applied to the material thus obtained from wood; this was earlier known as coal simply, until mineral coal (q.v.) came into use. When the production of charcoal as such for domestic cooking and heating and for metallurgical purposes originally began is unknown, but the smelting of metals from their ores was practised before 4,000 B.C. and charcoal was the only known fuel capable of producing the high temperatures necessary.

Wood consists essentially of carbon, hydrogen and oxygen, but the latter two elements are present in the same proportions as in water. During the combustion of wood only the carbon contributes towards the heat released, and a proportion of this becomes used in evaporating the moisture in the wood, of which even seasoned timber contains 15-20%. If wood is first converted into charcoal this burns with intense heat, without any visible flame and has about twice the heating power of the same weight of wood. These properties and the high chemical activity of charcoal compared with most other forms of carbon (cf. diamond as the other extreme) are responsible for its economic importance.

Throughout the middle ages the increasing demands for fuel for metal-smelting and glass-making led to the concentration of these industries in the European forest lands, some of which became relatively densely populated. Much of the deforestation of Europe during this period can be attributed to charcoal-burning. In spite of legal restrictions the process continued: in England, the Sussex Weald and the Midland forests were cut; yet towards the end of the 16th century Archbishop Grindal could complain of the smoke caused by charcoal-burners at Croydon, so that timber must still have been available there. By the beginning of the 20th century 95% of the forests which once covered Great Britain had been felled and in parts of western Europe the proportion was nearly as high. The evolution during the 18th century of metallurgical processes using coke prevented complete denudation of the European forests. Charcoal is now little used for iron-smelting except in remote ore-fields without local coal supplies (e.g. Zapla, in Argentina), but metallurgical operations requiring a carbonaceous material of low ash content, especially sulphur and phosphorus, still consume large quantities.

Preparation.--Wood charcoal was formerly produced by slow partial combustion of wood in circular stacks (Ger. Meiler, hence 'meiler charcoal') with a central chimney. When this process is now used the stacks contain about 200 cu. yd. of material and two to three weeks are required for its completion; with skilled attention the yield approaches 26% by weight of the wood or 60% by bulk. To avoid the loss of many valuable by-products into the atmosphere, carbonization is now carried out in kilns or retorts fitted with condensers. The former are of either beehive or rectangular shape, externally fired and may contain 250-400 cu. yd. of wood. The temperature is raised in stages first to about 275° C, when an exothermic reaction occurs, then to 400 or 500° C; the process normally takes up to three weeks but can be shortened by the use of forced draught. The main liquid product is Stockholm tar or creosote, a valuable preservative for timber (see Tar).

Better yields of both charcoal and distillates are obtained with retorts; the process was introduced into England in 1783 when an improved quality of charcoal was required for making gunpowder. For this purpose light woods such as alder or willow are best. During the second world war small portable kilns were designed for use in Britain and elsewhere. Sporting cartridge powder often contains red charcoal or charbon roux, prepared by subjecting wood to superheated steam at two atmospheres pressure in iron cylinders.

Recently, especially in the United States, low temperatures (200° rising to 340° C) have been employed for the distillation of wood; this and the selection of woods to give the maximum volume of liquid reduce the quantity and quality of charcoal, which becomes a by-product, but a variety of spirits and oils in addition to creosote are obtained. Formerly horizontal iron retorts were used but in modern American practice the process is continuous, wood being fed in at the top of the retort and charcoal withdrawn at the base. A Swiss process, also continuous, utilizes furnace gases for direct heating of the wood. In Scandinavia horizontal tube ovens and large vertical iron retorts containing 500 cu. yd. of wood are employed.

The residue of charcoal from distillation is usually 20-35% by weight; in addition 10-40 gallons of turpentine, up to 120 gallons of resin oil and creosote, and smaller amounts of acetic acid, wood spirit (methyl alcohol) and various oils are obtained per cord (c. 4,000 lb.) of wood. Inflammable gas and pitch are also produced.

A 'charcoal' or char can be prepared by carbonizing peat and various commercial processes for its manufacture have been operated but none has proved an economic success in the long run.

Properties.--Wood charcoal retains the original shape and cell structure of the wood from which it is made, rings when struck and has a bright fracture; it is tasteless and odourless. Its apparent density ranges from 0.1 gm/ml if made from soft wood to 0.5 if made from hard wood. Its calorific value varies from 12,000 to 14,000 B.Th.U./lb. Excluding the associated mineral matter the composition of a typical 'meiler charcoal' prepared at 500°C corresponds approximately to the formula $C_{16}H_6O$; the proportion of carbon increases with higher carbonization temperatures. In the literature the 'carbon' content of a charcoal is frequently referred to as the residue after re-carbonizing to a high temperature; this ignores the carbon present in volatile matter driven off and the appreciable hydrogen and oxygen content of the residue. The non-combustible portion, usually amounting in a commercial charcoal to 1-5% by weight on the dry basis, consists of adventitious matter and the mineral residues from plant cells, the latter being mainly phosphates, carbonates, silicates, chlorides and sulphates of the elements Na, K, Mg, Ca, Fe, and Mn. Owing to its capacity for absorbing gases and vapours, charcoal normally contains up to 9% of moisture.

One of the principal uses of wood charcoal to-day is for the manufacture of carbon disulphide. Beech or birch wood yields the best charcoal for this purpose and its reactivity is highest when the carbonization temperature does not exceed about 500°C. In countries with ample timber resources but dependent on imported petroleum supplies (e.g. France and Australia) charcoal has been used as a fuel for mobile gas generators. The low density of the fuel and size of the generator have, however, tended to restrict this application.

When wood charcoal, especially that made from coconut shell, is kept at red heat for many hours, with only limited access of air, its capacity for adsorption (q.v.) of gases is greatly enhanced; it is then said to be active.

TANNING

The directions for tanning need not be memorized, but they must be studied carefully until thoroughly understood before the work is begun. All supplies and equipment should be on hand and all plans should be carefully made before the work is started. It may be necessary to modify the directions, especially those dealing with equipment or tanning conditions. Success in modifying them depends largely upon the individual.

Tanning operations are done best at a uniformly moderate temperature. A cellar, which is naturally fairly warm in winter and cool in summer, is a suitable place. A supply of fresh water near at hand and a drain are convenient.

All the operations can be done in tight, clean wooden barrels, preferably oak, having a capacity of from 40 to 60 gallons. When not in use the barrels should be kept clean and full of water. Half barrels and wooden or fiber buckets are useful for many purposes. Iron containers should never be used. Tools useful in tanning are shown in figure 1.

TANNING HIDES AND SKINS FOR LEATHER

The kind of leather which can be made from a hide or skin depends largely upon the weight and size of the hide or skin. In the tanning trade distinctions in hides and skins are based mainly upon the size and age of the animal and upon the class of leather. Hides from large and adult animals are suitable for sole, harness, belting, or heavy leathers. Skins from small animals, such as sheep, goats, calves, and deer, are made into light and fancy leathers. While there are other commercially important sources of hides and skins, the most important ones are the usual domesticated farm and range animals. As a general rule, the thickness of the finished leather will be about the same as that of the untanned hide. This should be a guide in selecting skins for different kinds of leather. The first essential for a satisfactory yield of good leather is a sound, clean hide or skin. Skinning should be done properly, without cutting or scoring the hide, and at the same time all of the fat and flesh should be removed; for, if left on, they increase the tendency of the hide to rot or spoil. Farmers' Bulletin 1055, Country Hides and Skins: Skinning, Curing, and Marketing, should be studied in this connection.

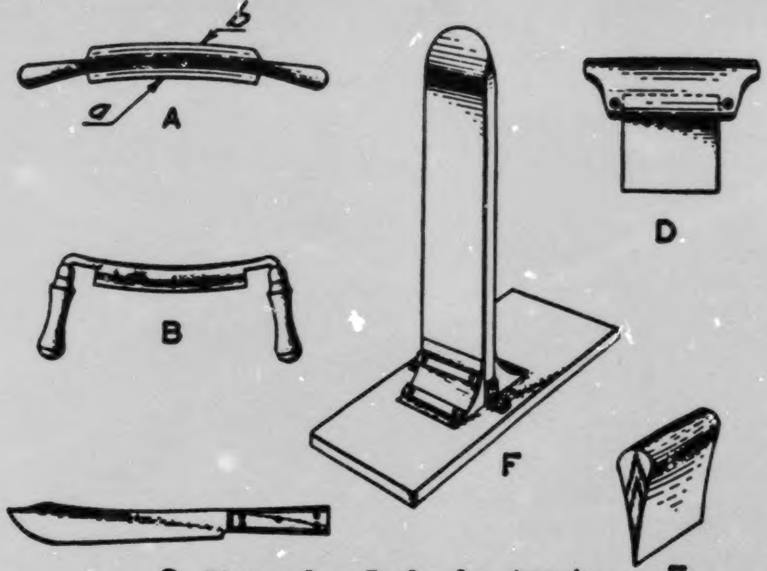


Figure 1.--Tools for tanning

(A) Tanner's fleshing knife, having a blade 15 to 17 inches long: (a) Dull edge for scraping off the hair after liming; (b) very sharp edge for shaving off the flesh.

(B) Eight-inch blade drawing knife, which may be used instead of A, especially if both handles are bent straight. The back edge may be used for unhairing and the cutting edge for shaving off the flesh.

(C) Twelve-inch-blade butcher knife, which may be used instead of A or B when the point has been driven into a wooden handle or wrapped with leather.

(D) Metal slicker--a dull steel blade about 5 inches square, 1/32 to 1/16 inch thick, mounted in a wooden handle.

(E) Wooden slicker, made of hardwood, about 6 inches square, 1½ inches thick at head, shaved down in the shape of a wedge to a thin edge.

(F) Stake for breaking up and softening skins and leather. A board about 3 feet long, 6 inches wide, and 1 inch thick is braced in upright position to a heavy base or to the floor. The top of the board is rounded and thinned in the shape of a wedge to an edge about 1/8 inch thick.

Preparation of the hide or skin for tanning may be begun as soon as it has been taken off the animal, drained, and cooled from the body heat. Overnight will be long enough. If tanning is not to be started at once or if there are more hides than can be handled at one time, the hides may be thoroughly salted, using about 1 pound of clean salt for each pound of hide. They then may be kept for from 3 to 5 months. The hides must never be allowed to freeze or heat during storage or tanning. Some tanners state that salting before tanning is helpful. It can do no harm to salt a hide for a few days before it is prepared for tanning.

The directions here given have been prepared for a single heavy cow, steer, or bull hide weighing from 40 to 70 pounds or for an equivalent weight in smaller skins, such as calf or kip skins. The heavy hides are best suited for sole, harness, or belting leather. Lighter hides weighing from 20 to 40 pounds should be used for lace leather.

PRELIMINARY OPERATIONS

Before it is tanned a hide or skin must be put through the following preliminary operations, which are the same for all the leather-making processes given in this bulletin. As soon as the skin has been put through these processes, start the tanning, following the directions given for the particular kind of leather desired.

Soaking and Cleaning

If the hide has been salted, shake it vigorously to remove most of the salt. Spread it out, hair side down, and trim off the tail, head, all ragged edges, and shanks.

Place the hide, hair side up, lengthwise, over a smooth log or board, and with a sharp knife split it from neck to tail, straight down the backbone line, into two half hides, or "sides." It will be more convenient in the later handling, especially when the hide is large, to then split each side lengthwise through the "break," just above the flanks, into two strips, making the strip with the backbone edge about twice as wide as the belly strip. Thus a whole hide will give two sides or four strips. Small skins need not be split. In these directions "side " means side, strip, or skin, as the case may be.

Fill a 50-gallon barrel with clean, cool water. Place the sides, flesh side out, over short sticks and hang them in the barrel of water. The sticks must be short enough to fit crosswise in the barrel and should have a cord or small rope, a foot or so long, attached to each end. The cords or ropes are fastened to nails on the outside of the barrel after adjusting them so the sides are completely covered by water. Let the sides soak for 2 or 3 hours. Stir them about frequently to soften, loosen, and wash out the blood, dirt, manure, and salt.

After they have soaked for about 3 hours take out the sides, one at a time, and place them, hair side up, over a "beam." A ready-made beam can be bought. A fairly satisfactory one may be made from a very smooth slab, log, or thick planed board, from 1 to 2 feet wide and 6 to 8 feet long. The slab or log is inclined, with one end resting on the ground and the other extending over a box or trestle so as to be about waist high. With the side lying hair side up over the beam scrub off all dirt and manure, using if necessary a stiff brush. Wash off with several bucketfuls of clean water.

Turn the side over, flesh side up, and scrape or cut off any remaining flesh. Work over the entire flesh side with the back edge of a drawing or butcher knife held firmly against the hide, pushing away from the body. Wash off with one or two bucketfuls of clean water. This working over should always be done.

Refill the soak barrel with clean, cool water and hang the sides in it as before. Pull them up and stir them about frequently until they are soft and flexible. Usually a green or fresh hide needs to be soaked for not more than from 12 to 24 hours and a green salted hide for not more than from 24 to 48 hours.

When the sides are properly softened--that is, when they are about like a fresh hide or skin--throw them over the beam and thoroughly scrape off all remaining flesh and fat.

The side must be soft, pliable, and clean all over before being put into the lime, which is the next step.

Liming

Wash out the soak barrel, put in from 9 to 11 pounds of hydrated lime (use lime from a fresh bag, not old, air-slaked lime) and 4 or 5 gallons of water. Stir with a paddle until the lime is thoroughly mixed with the water, then nearly fill the barrel with clean, cool water and again stir thoroughly. Again place the sides, hair side out, over the short sticks and hang them in the barrel so that they are completely covered by the limewater. See that the sides have as few folds or wrinkles as possible, and also be sure that no air is trapped under them. Keep the barrel covered with boards or bags. Pull up the sides and stir the limewater three or four times each day until the hair will come off easily. This takes from 6 to 10 days in summer and possibly as many as 16 days in winter.

When thoroughly limed, the hair can be rubbed off readily with the hand. Early in the liming process it will be possible to pull out the hair, but the hide must be left in the limewater until the hair comes off by rubbing over with the hand. For harness and belting leathers leave the hide in the limewater for from 3 to 5 days after this condition has been reached.

Unhairing

After the side has been limed, throw it hair side up, over the beam and with the back edge of a drawing or butcher knife held nearly flat against the side push off the hair from all parts. If the side is sufficiently limed, a curdy or cheesy layer of skin rubs off with the hair. If this layer does not rub off, the side must be returned to the limewater. Now thoroughly work over the grain or hair side with a dull-edged tool to "scud" or work out as much lime, grease, and dirt as possible.

Fleshing

Turn the side over and scud it again, being sure to remove all fleshing matter. Shave down to the hide itself, but be careful not to cut into it. Remove the flesh by scraping and by using a very sharp knife, with a motion like that of shaving the face.

Now proceed as directed under Bark-Tanned Sole and Harness Leather, Chrome-Tanned Leather, or Alum-Tanned Lace Leather, depending upon the kind of leather desired.

Wastes From Liming

The lime, limewater, sludge, and fleshings from the liming process may be used as fertilizer, particularly for acid soils. The hair, as it is scraped from the hide, may be collected separately and after being rinsed several times may be used for plastering. If desired, it can be thoroughly washed with many changes of water until absolutely clean and after being dried out in a warm place used for padding, upholstering, insulation of pipes, etc.

BARK-TANNED SOLE AND HARNESS LEATHER

Deliming

After the sides have been put through the unhairing and fleshing operations, rinse them with clean water. Wash the sides in cool, clean water for from 6 to 8 hours, changing the water frequently.

Buy 5 ounces of U. S. P. (United States Pharmacopoeia) lactic acid (or 16 ounces of tannery 22 percent lactic acid). Nearly fill a clean 40- to 50-gallon barrel with clean, cool water, stir in the lactic acid, and mix the water and acid thoroughly with a paddle. Hang the sides in the barrel and leave them there for 24 hours, pulling them up and stirring them frequently.

Take out the sides, work over or scud them thoroughly, as directed under Unhairing, and hang them in a barrel of cold water. Change the water several times, and finally leave them in the water overnight.

If lactic acid cannot be obtained, use a gallon of vinegar instead.

Tanning

The sides are now ready for the actual tanning. From 15 to 20 days before this stage will be reached, weigh out from 30 to 40 pounds of good quality, finely ground oak or hemlock bark and pour onto it about 20 gallons of boiling water.

Finely ground bark, with no particles larger than a grain of corn, will give the best results. Simply chopping the bark into coarse pieces will not do. Do not let the tan liquor come into contact with iron vessels. Use the purest water available. Rain water is best.

Let this bark infusion stand in a covered vessel until ready for use. Stir it occasionally. When ready to start tanning, strain off the bark liquor through a clean, coarse sack into the tanning barrel. Fill the barrel about three-quarters full with water, rinsing the bark with this water so as to get out as much tannin as possible. Add 2 quarts of vinegar. Stir well. Place the sides, from the deliming, over sticks, and hang them in this bark liquor with as few folds and wrinkles as possible. Move the sides about and change their position often in order to get an even color.

Just as soon as the sides have been hung in the bark liquor, again soak from 30 to 40 pounds of ground bark in about 20 gallons of hot water. Let this second bark liquor stand until the sides have become evenly colored, or for from 10 to 15 days. Take out of the tanning barrel 5 gallons of liquor and pour in about one-quarter of the second bark liquor. Also add about 2 quarts more of vinegar and stir it in well. Five days later take out a second 5 gallons of tanning liquor from the barrel and add another fourth of the tan liquor only (no vinegar). Do this every 5 days until the second bark liquor is used up.

The progress of the tanning varies somewhat with conditions and can best be followed by inspecting a small sliver cut from the edge of the hide. About 35 days after the actual tanning has been started a fresh cut should show two dark or brown narrow streaks about as wide as a heavy pencil line coming in from each surface of the hide.

At this stage weigh out about 40 pounds of fine bark and just moisten it with hot water. Do not add more water than the bark will soak up. Pull the sides out of the bark liquor and dump in the moistened bark, keeping in the barrel as much of the old tan liquor as possible. Mix thoroughly and while mixing hang the sides back in the barrel. Actually bury them in the bark. All parts of the sides must be kept well down in the bark mixture. Leave the sides in this bark for about 6 weeks and move them about once in a while.

At the end of 6 weeks pull the sides out. A cutting should show that the tanning has spread nearer to the center. Pour out about half the liquor. Stir the bark in the barrel, hang the sides back, and fill the barrel with fresh, finely ground bark. Leave the sides in for about 2 months, shaking the barrel from time to time and adding bark and water as needed to keep the sides completely covered.

At the end of this time the hide should be evenly colored all the way through, without any white or raw streak in the center of a cut edge. If it is not struck through, it must be left longer in the wet bark, and more bark may be needed.

For harness, strap, and belting leather the sides may be taken out of the bark liquor at this stage, but for sole leather they must be left for 2 months longer. When fully tanned through, the sides are ready for oiling and finishing.

Oiling and Finishing

HARNESS AND BELTING LEATHER.--Take the sides from the tan liquor, rinse them off with water, and scour the grain or hair side thoroughly with plenty of warm water and a stiff brush. Then go over the sides with a "slicker", pressing the slicker firmly against the leather while pushing it away from the body and work out as much water as possible. "Slick" out on the grain or hair side in all directions. For harness, belting, and the like this scouring and slicking must be done thoroughly.

A slicker can be made from a piece of copper or brass about one-fourth inch thick, 6 inches long, and 4 inches wide. One long edge of the slicker is mounted in a wooden handle and the other long edge is finished smooth and well rounded. A piece of hardwood, about 6 inches square, 1½ inches thick at the head, and shaved down wedge-shape to a thin edge will also serve as a slicker.

While the sides are still damp, but not very wet, go over the grain or hair side with a liberal coating of neat's-foot or cod oil. Hang up the sides and let them dry out slowly. When dry, take them down and dampen well by dipping in water or by rolling them up in wet sacking or burlap.

When uniformly damp and limber, evenly brush or mop over the grain or hair side a thick coating of warm dubbin. The dubbin is made by melting together about equal parts of cod oil and tallow or neat's-foot oil and tallow. This dubbin when cool must be soft and pasty, but not liquid.

Hang up the sides again and leave until thoroughly dry. When dry, scrape off the excess tallow by working over with the slicker. If more grease in the leather is desired, dampen again and apply another coating of the dubbin, giving a light application to the flesh side also. When again dry, remove the tallow and thoroughly work over all parts of the leather with the slicker. Rubbing over with sawdust will help to take up any surface oiliness.

If it is desired to blacken the leather, this must be done before greasing. A black dye solution can be made by dissolving one-half ounce of water-soluble nigrosine in 1¼ pints of water, with the addition, if handy, of several drops of ammonia. Evenly mop or brush this solution over the dampened but ungreased leather and then grease as directed in the preceding paragraph.

SOLE LEATHER.--Take the sides from the tan liquor and rinse them thoroughly with clean water. Slick out on the grain or hair side as described for harness leather. Hang them up until they are only damp and then apply a good coating of neat's-foot oil or cod oil to the grain or hair side. Again hang them up until they are thoroughly dry.

When repairing shoes with this leather it is advisable, after cutting out the piece for soling, to dampen and hammer it down well, and then, after putting it on the shoe, to make it waterproof and more serviceable by setting the shoe in a shallow pan of melted grease or oil and letting it stand for about 15 minutes. The grease or oil must be no hotter than the hand can bear. Rubber heels should not be put in oil or grease. The soles of shoes with rubber heels may be waterproofed in the same way, using a piepan for the oil or grease and placing the heels outside the pan. Any good oil or grease will do. The following formulas have been found satisfactory:

	Ounces
Formula 1:	
Neutral wool grease	8
Dark petrolatum	4
Paraffin wax	4
Formula 2:	
Petrolatum	16
Beeswax	2
Formula 3:	
Petrolatum	8
Paraffin wax	4
Wool grease	4
Crude turpentine gum (gum thus)	2
Formula 4:	
Tallow	12
Cod oil	4

CHROME-TANNED LEATHER

For many purposes chrome-tanned leather is considered to be as good as the more generally known bark or vegetable-tanned leather. The chrome process, which takes only a few weeks as against as many months for the bark-tanning process, derives its name from the use of chemicals containing chromium. It is a chemical process requiring great care. It is felt, however, that by following exactly the directions here given, never disregarding details which may seem unimportant, a serviceable leather can be produced in a comparatively short time. The saving in time seems sufficient to justify a trial of this process.

Deliming

After the sides have been put through the unhairing and fleshing operations rinse them off with clear water.

If sole, belting, or harness leather is to be tanned, soak and wash the sides in cool water for about 6 hours before putting them into the lactic acid. Change the water four or five times.

If strap, upper, or thin leather is to be tanned, put the limed white sides into a wooden or fiber tub of clean, lukewarm (about 90° F.) water and let them stay there for from 4 to 8 hours before putting them into the lactic acid. Stir the sides about occasionally. Be sure that the water is not too hot. It never should be so hot that it is uncomfortably warm to the hand.

For each large hide or skin buy 5 ounces of U. S. P. lactic acid (or 16 ounces of tannery 22 percent lactic acid). Nearly fill a clean 40- to 50-gallon barrel with clean, cool water, and stir in the latic acid, mixing thoroughly with a paddle. Hang the sides in the barrel, and leave them there for 24 hours, plunging them up and down occasionally.

For light skins, weighing less than 15 pounds, use only 2 ounces of U. S. P. lactic acid in about 20 gallons of water.

If lactic acid cannot be obtained, use 1 pint of vinegar for every ounce of lactic acid. An effort should be made to get the lactic acid, however, for vinegar will not be as satisfactory, especially for the medium and smaller skins.

After deliming, work over both sides of the side as directed under Unhairing.

For sole, belting, and harness leathers, hang the sides in a barrel of cool water overnight. Then proceed as directed under Tanning.

For thin, softer leathers from small skins, do not soak the sides in water overnight. Simply rinse them off with water and proceed as directed under Tanning.

Tanning

The tanning solution should be made up at least 2 days before it is to be used--that is, not later than when the sides are taken from the limewater for the last time.

Remember that this is a chemical process and that all materials must be of good quality and accurately weighed and the specified quantities of water carefully measured.

The following chemicals are required: Chrome alum (chromium potassium sulfate crystals); soda crystals (crystallized sodium carbonate); and common salt (sodium chloride). Insist upon pure chemicals of the United States Pharmacopoeia quality. Get them from the nearest drugstore or find out from it the address of a chemical manufacturing concern which can supply them.

For each hide or skin weighing more than 30 pounds use the following quantities for the stock chrome solution:

Dissolve 3½ pounds of soda crystals (crystallized sodium carbonate) and 6 pounds of common salt (sodium chloride) in 3 gallons of warm, clean water in a wooden or fiber bucket. The soda crystals must be clear or glasslike. Do not use the white crusted lumps.

At the same time dissolve in a large tub or half barrel 12 pounds of chrome alum (chromium potassium sulfate crystals) in 9 gallons of cool, clean water. This will take some time to dissolve and will need frequent stirring. Here again it is important to use only the very dark, hard, glossy, purple or plum-colored crystals of chrome alum, not the lighter, crumbly, dull-lavender ones.

When the chemicals are dissolved, which can be told by feeling around in the tubs with a paddle, pour the soda-salt solution slowly in a thin stream into the chrome-alum solution, stirring constantly.

Take at least 10 minutes to pour in the soda solution. This should give one solution of about 12 gallons, which is the stock chrome solution. Keep this solution well covered in a wooden or fiber bucket, tub, or half barrel.

To start tanning, pour one-third (4 gallons) of the stock chrome solution into a clean 50-gallon barrel and add about 30 gallons of clean, cool water; that is, fill the barrel about two-thirds full. Thoroughly mix the solution in the barrel and hang in it the sides from the deliming. Work the sides about and stir the solution frequently, especially during the first 2 or 3 days. This helps to give the sides an even color. It should be done every hour or so throughout the first day. Keep the sides as smooth as possible.

After 3 days, temporarily remove the sides from the barrel. Add one-half of the remaining stock chrome solution, thoroughly mixing it with that in the barrel, and again hang in the sides. Move the sides about and stir frequently as before.

After the sides have been in this solution for 3 or 4 days, cut off a small piece of the thickest part of the side, usually in the neck, and examine the freshly cut edge of the piece. If the cut edge seems to be evenly colored greenish or bluish all the way through, the tanning is about finished. Boil the small piece in water for a few minutes. If it curls up and becomes hard or rubbery, the tanning is not completed and the sides must be left in the tanning solution for a few days longer, or until a small piece when boiled in water is changed little if at all.

The foregoing quantities and directions have been given for a medium or large hide. For smaller hides and skins the quantities of chemicals and water can be reduced. For each hide or skin weighing less than 30 pounds, or for two or three small skins together weighing not more than 30 pounds, the quantities of chemicals may be cut in half, giving the following solutions:

For the soda-salt solution, dissolve 1 3/4 pounds of soda crystals (crystallized sodium carbonate) and 3 pounds of common salt (sodium chloride) in 1½ gallons of clean water.

For the chrome-alum solution, dissolve 6 pounds of chrome alum (chromium potassium sulfate crystals) in 4½ gallons of cool, clean water.

When the chemicals are dissolved pour the soda-salt solution slowly into the chrome-alum solution as already described. This will give one solution of about 6 gallons which is the stock chrome solution. For the lighter skins tan with this solution, exactly as directed for medium and large hides, adding one-third, that is, 2 gallons, of this stock chrome solution each time, and begin to tan in about 15 gallons instead of 30 gallons of water. Follow the directions already given as to stirring, number of days, and testing to determine when tanning is completed. Very small, thin skins probably will not take as long to tan as will the large hides. The boiling-water test is very reliable for showing when the hide is tanned.

Washing and Neutralizing

When the sides are tanned, take them out of the tanning solution and put them in a barrel of clean water. The barrel in which the tanning was done can be used after it has been thoroughly washed.

When emptying the tanning barrel be sure carefully to dispose of the tanning solution. Although not poisonous to the touch, it probably would be fatal to farm animals should they drink it, and it is harmful to soil.

Wash the sides in about four changes of water. For medium and large hides, dissolve 2 pounds of borax in about 40 gallons of clean water and soak the sides in this solution overnight. For hides and skins weighing less than 25 pounds, use 1 pound of borax in about 20 gallons of water. Move the sides about in the borax solution as often as feasible. After soaking overnight in the borax solution, remove the sides and wash them for an entire day, changing the water five or six times. Take the sides out, let the water drain off, and proceed as directed under Dyeing Black, or, if it is not desired to blacken the leather, proceed as directed under Oiling and Finishing.

Dyeing Black

WATER-SOLUBLE NIGROSINE.--One of the simplest and best means of dyeing leather black is to use nigrosine. Make up the dye solution in the proportion of one-half ounce of water-soluble nigrosine dissolved in 1¼ pints of water. Be sure to get water-soluble nigrosine.

Evenly mop or brush this solution over the damp leather after draining as already directed and then proceed as directed under Oiling and Finishing.

IRON LIQUOR AND SUMAC.--If water-soluble nigrosine cannot be obtained, a fairly good black may be secured with iron liquor and sumac. To make the iron liquor, mix clean iron filings or turnings with one-half gallon of good vinegar and let the mixture stand for several days. See that there are always some undissolved filings or turnings in the vinegar. For a medium or large hide put from 10 to 15 pounds of dried crumbled sumac leaves in a barrel containing from 35 to 40 gallons of warm water. Stir well and when cool hang in it the wet, chrome-tanned sides. If you cannot get sumac leaves, use 20 or 30 pounds of finely chopped oak or hemlock bark but pour hot water on the bark and let stand a couple of days before use. Leave the sides in this solution for about 2 days, pulling them up and mixing the solution frequently. Take out the sides, rinse off all bits of sumac, and evenly mop or brush over with the iron liquor. Rinse off the excess of iron liquor and put the sides back in the sumac overnight. If not black enough the next morning, mop over again with iron liquor, rinse, and return to the sumac solution for a day. Take the sides out of the sumac, rinse well, and scrub thoroughly with warm water. Finally wash the sides for a few hours in several changes of water.

While both of these formulas of dyeing have been given, it is recommended that water-soluble nigrosine be used whenever possible, as the iron liquor and sumac formula is somewhat troublesome and may produce a cracky grain. After blackening, proceed as directed under Oiling and Finishing.

Oiling and Finishing

THIN LEATHER.--Let the wet tanned leather from the dyeing, or, if not dyed, from the neutralizing, dry out slowly. While it is still very damp go over the grain or hair side with a liberal coating of neat's-foot or cod oil. While still damp, tack the sides out on a wall or tie them in frames (shown on cover), being sure to pull them out tight and smooth, and leave them until dry. When dry take down and dampen well by dipping in warm water or by rolling them up in wet sacking or burlap. When uniformly damp and limber go over the sides with a "slicker", pressing the slicker firmly against the leather, while pushing it away from the body. Slick out on the grain or hair side in all directions.

After slicking it may be necessary to "stake" the leather. This is done by pulling the damp leather vigorously back and forth over the edge of a small smooth board about 3 feet long, 6 inches wide, and 1 inch thick, fastened upright and braced to the floor or ground. The top end of the board must be shaved down to a wedge shape, with the edge not more than one-eighth inch thick and the corners well-rounded. Pull the sides, flesh side down, backward and forward over this edge, exactly as a cloth is worked back and forth in polishing shoes.

Let the sides dry out thoroughly again. If not sufficiently soft and pliable, dampen them with water, apply more oil, and slick and stake as before. The more time given to slicking and staking, the smoother and more pliable the leather will be.

THICK LEATHER.--Thick leather from the larger hides is oiled and finished in a slightly different manner. For harness and strap leather, let the tanned sides, dyed if desired, dry down. While they are still quite damp slick over the grain or hair side thoroughly and apply a liberal coating of neat's-foot or cod oil. Tack on a wall or tie in a frame, stretching the leather out tight and smooth, and leave until dry. Take the sides down, dampen them with warm water until limber and pliable, and apply to the grain side a thick coating of warm dubbin. The dubbin is made by melting together about equal parts of cod oil and tallow or neat's-foot oil and tallow. When cool it must be soft and pasty but not liquid. If too nearly liquid, add more tallow. Hang up the sides again and leave them until thoroughly dried. When dry, scrape off the excess tallow by working over with the slicker. If more grease in the leather is desired, dampen again and apply another coating of the dubbin. When again dry, slick off the tallow and thoroughly work over all parts of the leather with the slicker. Rubbing over with sawdust helps to take up surface oiliness.

Chrome-tanned leather is stretchy, so that in cutting the leather for use in harness, straps, reins, and similar articles it is best to first take out most of the stretch.

Chrome leather for shoe soles must be heavily grease, or, in other words, waterproofed, unless it is to be worn in extremely dry regions. Waterproofing may be done after repairing the shoes by setting them in a shallow pan of oil or grease so that just the soles are covered by the grease. The soles should be dry before they are set in the melted grease. Melted paraffin wax will do, although it makes the soles stiff.

ALUM-TANNED LACE LEATHER

Deliming

After the sides have been put through the unhairing and fleshing operations, rinse them off with cool, clean water for from 6 to 8 hours, changing the water frequently.

Buy 5 ounces of U.S.P. lactic acid (or 16 ounces of tannery 22 percent lactic acid). Nearly fill a clean 40- to 50-gallon barrel with clean, cool water and stir in the lactic acid, mixing thoroughly with a paddle. Hang the sides in the barrel and leave them there for 24 hours, pulling them up and stirring them about frequently. Take out the sides, work over or scud thoroughly, as directed under Unhairing, and hang them in a barrel of cool water. Change the water several times, and finally leave them in the water overnight. If lactic acid cannot be obtained, use a gallon of vinegar instead.

Tanning

While the sides are being delimed, thoroughly wash out the barrel in which the hide was limed. Put in it 15 gallons of clean water and 12 pounds of ammonia alum or potash alum and stir frequently until it is completely dissolved.

Dissolve 3 pounds of washing soda (crystallized sodium carbonate) and 6 pounds of salt in 5 gallons of cold, clean water in a wooden bucket. The soda crystals must be clear and glasslike. Do not use white crusted lumps.

Pour the soda solution into the alum solution in the barrel very, very slowly, stirring the solution in the barrel constantly. Take at least 10 minutes to pour in the soda solution in a small stream. If the soda is poured in rapidly the solution will become milky and will not tan. The solution should be cool, and enough water to nearly fill the barrel should be added.

Hang each well-washed side from the deliming in the alum-soda solution. Pull up the sides and stir the solution six or eight times each day. Do not put the bare hands in the liquor if they are cut or cracked or have sores on them.

After 6 or 7 days remove the sides from the alum-soda solution and rinse well for about a quarter of an hour in clean, cold water.

Oiling and Finishing

Let the sides drain and dry out slowly. While still very damp go over the grain or hair side with a liberal coating of neat's-foot or cod oil. After the oil has gone in and the sides have dried a little more but are still slightly damp, begin to work them over a "stake." The time to start staking is important. The sides must not be too damp; neither must they be too dry. When light spots or light streaks appear on folding it is time to begin staking. Alum-tanned leather must be thoroughly and frequently staked.

Staking is done by pulling the damp leather vigorously back and forth over the edge of a small, smooth board. The sides must be staked thoroughly all over in order to make them pliable and soft, and the staking must be continued at intervals until the leather is dry.

When dry, evenly dampen the sides by dipping them in water or by leaving them overnight covered with wet burlap or sacks. Apply to the or hair side a thick coating of warm dubbin. The dubbin is made by melting together about equal parts of neat's-foot oil and tallow or cod oil and tallow. When cool, the dubbin must be soft and pasty but not liquid. If too nearly liquid, add more tallow. Leave the greased sides, preferably in a warm place, until dry. Scrape off the excess tallow and again stake the sides. If the leather is too hard and stiff, dampen it evenly with water before staking.

After staking, go over the sides with a slicker, pressing the slicker firmly against the leather, while pushing it away from the body. Slick out on the grain, or hair side, in all directions.

Alum-tanned leather almost invariably dries out the first time hard and stiff. It must be dampened again and restaked while drying. In some cases this must be done repeatedly, and another application of dubbin may be necessary. By repeated dampening, staking, and slicking the leather can be made as soft and pliable as desired.

TANNING FUR SKINS

Much of the value of a fur skin depends upon the manner in which it is handled in the raw state. After the animal has been caught, every effort should be made to follow the best practices in skinning and curing, in order to obtain a skin of the greatest possible value. Certain trade customs also must be followed to secure the top price.

Requests for directions for tanning fur skins are constantly received by the Department of Agriculture. There is, however, less need for such information than there is for information on farm or home tanning of hides and skins into leather. Fur skins as a protection are a necessity for those living in cold climates, but comparatively few are used for this purpose. Most of the fur skins are made into articles which are more or less of a luxury and, as such, are valued largely on the basis of their appearance and finish, which an inexperienced worker can seldom make sufficiently pleasing. Furthermore, raw fur skins are valuable, and, if well cared for, usually find a ready market. Nevertheless, the spread between the prices paid for raw furs and those demanded for finished fur articles is enormous. No doubt, this spread in many instances inspires the attempts at home manufacture.

An inexperienced person should not try to tan valuable fur skins or large hides, such as cattle, horse, or bear, for making into coats, robes, or rugs. The risk of damage or of an unsatisfactory product, as measured by the usual standards of finish and appearance, is too great. The difficulties in properly handling large hides make the chances of success remote, except by those having suitable equipment and experience. Moreover, tanning the skin is only one step in the production of the finished article. After being tanned, all skins must be tailored, many must be dyed, and small ones must be matched, blended, and sewed together. All these operations require experience and practice to secure the attractive appearance desired by wearers of furs. Some of the operations, such as those of bleaching and dyeing, are so highly specialized that their undertaking should not even be considered by an amateur. From the standpoint of serviceability and usefulness, inexperienced persons might meet with a fair degree of success in tanning and tailoring fur skins, but few can ever hope to make a fur piece or garment which will compare favorably in appearance with the shop or factory product. The tanning and dressing of fur skins, then, are best left to those who are experienced and equipped to carry out the tedious operations required.

To satisfy the demand upon the Department for information on the home tanning of fur skins and to provide those who insist upon carrying on such work with correct information and with detailed methods which offer the best chances for success, the following directions are given. These directions are meant primarily for small fur skins no larger than that of the fox and for skins of low market value.

No formulas for tanning are foolproof, and success can be attained only by close observation, plenty of work, and the exercise of care and patience. All skins are not treated just alike. In fact, each skin has its own peculiarities, which only experience can show how to treat. Some skins are tough and fairly thick and will stand mistreatment; others are very thin and tender and are easily ruined. Some are fat and greasy and require thorough working out of the grease; others do not. An inexperienced person should experiment with the least valuable skins. If a number of skins of the same kind are to be tanned, one or two of the poorest should be tried first.

Soaking and Fleshing

The first step is to get the skin thoroughly softened, cleaned, and free from flesh and grease.

Split the tail the entire length on the underside. If the skin is "cased," split it neatly down the middle of the belly. Soak it in several changes of clear, cool water. When the skin begins to soften, lay it on a beam or smooth pole and begin working over the flesh side to break up the adhering tissue and fat. All dried skins have a shiny, tight layer of tissue. This tissue must be broken up and entirely removed, which is best done by repeated alternate working and soaking. A good tool for scratching the tissue is a metal edge of any kind, such as a drawing knife or an ordinary knife with dull saw teeth or notches filed in it. Working over with these dull teeth scratches or breaks up the tissue so that it can be scraped off after further soaking.

At the same time the grease and oil are worked out of the skin. This operation is of the utmost importance. It is utterly useless to start tanning until all the tissue and grease have been removed and the skin is uniformly soft and pliable, without any hard spots.

The time of soaking depends upon the condition of the skin. Some skins require only about 2 hours, while others need a much longer time. Very hard skins often must be thoroughly dampened, rolled up, fur side out, and put away in a cool place overnight to soften. While a skin must be soaked until soft, it should not stay wet longer than necessary, as the hair may start to slip.

In fleshing and scraping, care also must be taken not to injure the true skin or expose the hair roots, especially on thin skins.

When the soaking is well advanced and the skin is getting in good shape, work it in lukewarm water containing an ounce of soda or borax to the gallon. Soap also may be added. This treatment promotes softening, cleans the skin, and cuts the grease.

Work again over the beam and finally rinse thoroughly in lukewarm water. Squeeze out most of the water, but do not wring the skin. Without further drying, work the skin in gasoline, using several changes if very much dirt and grease are present. Squeeze and hang up the skin for a few minutes.

The skin should now be ready for tanning. When painting or pasting of the tan liquor on the flesh side only is included in the directions for tanning, it is best to dry out the hair or fur side first by working in sawdust. In this way any heating of the fur side while the skin is tacked out is avoided, as are also matting and stiffening of the fur. If while drying out the fur, the flesh side becomes too dry, it must be evenly dampened with a wet cloth before applying the tan liquor.

Combination Tannage

A combination tannage is a combination of mineral and vegetable tanning. It has an advantage over the salt-acid or salt-alum processes in giving a soft and flexible skin, as well as a more lasting tannage.

One of the most popular and successful formulas for a combination tannage is given by M. C. Lamb. A pasty mixture of alum, salt, gambier, and flour, with or without glycerin or olive oil, is made as follows: Dissolve 1 pound of aluminum sulfate and 1 pound of salt together in a small quantity of water. Dissolve 3 ounces of gambier or Terra Japonica in a little boiling water. (Instead of gambier, 3 or 4 ounces of finely powdered sumac leaves may be used.) Mix the two solutions and make up to 2 gallons with water. As this solution is used, mix it with enough flour to make a moderately thin paste. If the skin has a hard texture and lacks natural grease, thoroughly mix a little olive oil or glycerin with the paste.

Soak, soften, and clean the skin as previously described and tack it out flat and smooth, flesh side up. Apply from two to three coatings of the paste, depending upon the thickness of the skin. Only thick skins require three coatings. Each coating should be about one-eighth inch thick and should be applied at intervals of a day. Between applications the skin should be kept covered with sacking or paper. Scrape off most of the old coating before putting on a new one. After the last coating has been applied, spread out the skin uncovered or hang it up to dry slowly.

When practically dry, wash off the flour paste, rinse for several minutes in water containing an ounce of borax to the gallon, then in water alone. Squeeze out most of the water. Put the skin over a beam and slick it out well on the flesh side with the back of a knife or edge of a wooden slicker, thus working out most of the water. Again tack the skin out smoothly, flesh side up, and apply a thin coating of any animal fat, fresh butter, being particularly good, or a nondrying oil, such as neat's-foot, castor, or olive oil. Glycerin or a soap may be used instead of the grease or oil. If the skin originally was very greasy. it may not be necessary to apply any oil.

When nearly dry, but still slightly damp, begin to work the skin in all directions, stretching it from corner to corner and working the flesh side over a stake or a wooden edge, such as the back of a chair or piece of board clamped in a vice.

The time to begin working is important and is best judged from experience. The skin must not be too wet; neither must it be too dry. The appearance of a few light spots or a light streak on folding is a good indication of the time to start working the skin.

Work the skin in all directions back and forth, as if shining shoes with a cloth. The skin may also be worked this way through smooth metal rings. Much of the success in getting a soft skin lies in this repeated working, which must be done while the skin is drying out, not after it is dry. If the skin is not soft enough when dry, it must be evenly dampened and worked again while drying. This may be repeated several times if necessary.

After softening and drying out it is well to give the skin a hasty bath in gasoline. If the skin is greasy, this must be done. This also helps to deodorize some skins, such as those of the skunk.

Finally, to clean and brighten the tanned skin, tumble or work it repeatedly in dry, warm sawdust, preferably hardwood sawdust, or bran or cornmeal. Clean these out of the fur by gentle shaking, beating, combing, and brushing.

The flesh side may be smoothed if necessary by working over a sandpaper block. This also helps to soften the skin further. If desired, the thicker sections of the skin may be made thinner and more flexible by shaving off some of the skin or hide.

Salt-Alum Tannage

The salt-alum process, an old method for furskin tanning, is widely used. It is considered slightly better than the salt-acid tannage, being a little more permanent and, when properly carried out, giving skins which have a little more stretch and flexibility. It often happens, however, that alum-tanned skins come out stiff and hard and must be worked repeatedly and sometimes retanned.

A salt-alum tanning solution may be made up using the following proportions: 1 pound of ammonia alum or potash alum dissolved in 1 gallon of water; 4 ounces of washing soda (crystallized sodium carbonate) and 8 ounces of salt, dissolved together in one-half gallon of water. When dissolved, pour the soda-salt solution very slowly into the alum solution while stirring vigorously.

A skin, cleaned and softened as previously described, may be tanned by immersion in this solution for from 2 to 5 days, depending upon its thickness. Because of the action of alum on some furs it may be best, as a general rule, to apply the tanning liquor as a paste to the flesh side only.

Mix the tan liquor as used with sufficient flour to make a this paste. Add the flour in small quantities with a little water and mix thoroughly to avoid lumps. Tack the skin out smoothly, flesh side up. Apply a coating of the paste about one-eighth inch thick and cover the skin. The next day scrape off most of the paste and give another coating. Apply altogether, at intervals of a day, from two to three coatings, depending upon the thickness of the skin. Only thick skins should need as many as three treatments. Leave the last coating on for 3 or 4 days. Finally scrape off and rinse clean in water, putting in about an ounce of borax to a gallon of water. Rinse at last in water only.

Work over a beam to remove most of the water. Stretch the skin out flat and sponge over the flesh side with a thin soap paste. After this has gone in, apply a thin coating of oil. Leave the skin stretched out to dry, and while it is still damp, work and stake, wetting and working repeatedly if necessary. Finally, clean in gasoline and sawdust and finish as described above.

Salt-Acid Tannage

One of the oldest processes of tanning requires various mixtures of common salt and sulfuric acid. Tanning, or, more correctly speaking, tawing, by this means is open to the objection that sulfuric acid must be used very cautiously, and must be completely neutralized to prevent later damage to the skin. Skins tanned with salt and acid also show a tendency to become damp and clammy in wet weather and, if repeatedly subjected to wetting, lose their tanned effect.

A salt-acid tanning solution may be made up in the following proportions: For each gallon of water use 1 pound of common salt and one-half ounce of concentrated sulfuric acid. Dissolve the salt and carefully pour in the acid while stirring. This tan liquor must be made and used in jars or wooden vessels, never in metal containers of any kind. (When pouring in the acid, do not inhale any more of the fumes given off than is necessary, and also be careful not to get any of the strong acid on the skin or clothing.) As soon as the acid-salt solution has cooled, it is ready for use.

Put the cleaned, softened skin in the solution so that it is entirely covered and leave it for from 1 to 3 days, depending upon its thickness. During this time stir the skin about frequently. If desired, the solution may be painted on instead. In this case, tack out the skin smoothly, flesh side up, paint over with the solution, and cover the skin with well-dampened sacking or cloth. At the end of 6 hours, paint over it again. With thicker skins, give one or two more applications of the solution about 6 hours apart, keeping the skin covered between applications. After the last application, hang up the skin or spread it, flesh side up, without cover, and let it dry.

After tanning, either by immersion or by painting, rinse the skin in clear water and squeeze out most of the water, but do not wring it. Then work the skin for about 10 minutes in a solution made up in the proportion of an ounce of borax in a gallon of water, and finally rinse well in clear water and squeeze.

Work over the skin with a slicker to remove most of the water, tack it out flat, flesh side up, and apply a thin coating of grease or oil. Leave the skin stretched to dry, and while it is still damp work and stake it.

Finally clean in gasoline and sawdust, and finish by shaking, beating, sandpapering, brushing, and combing.

HAND-LOOM WEAVING

A Simple Loom: In all hand weaving the loom is the structure forming a frame upon which the materials are woven. It would be quite possible to carry out simple weaving without a frame by attaching one end of a set of threads to a hook in a wall, holding the other ends, and working other threads across these. Therefore the loom or frame is merely a simple device to hold one set of threads firmly in position while working through them with another thread or threads. There are many types of looms, and I should like to make it quite clear that it is not essential for the beginner to commence with a simple, small loom and work through all the types of looms mentioned; the beginner can commence with quite a large loom, such as the four-shaft Kentish Loom, if it can be afforded. The purpose of describing the simple looms is to demonstrate by illustration and explanation the simple technique of weaving. However, it is suggested that construction of the loom illustrated in Fig. 1, and using it to practise the early stages of the work will assist the learner-weaver in appreciating the simplicity of the craft.

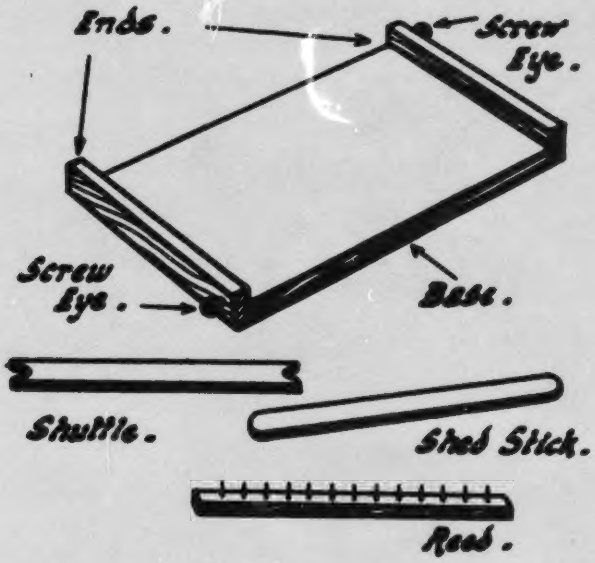


Fig. 1. A SIMPLE PRACTICE LOOM

The loom illustrated consists of a piece of wood, which is narrower than it is long, with two smaller pieces of wood fixed at each end. At the top left corner a small screw-eye is fitted and another screwed into the wood at the bottom right corner. To set up this simple loom, the end of a piece of long string should be firmly tied to the small screw-eye at the top-left corner, and the string wound round the wood frame in the manner illustrated in Fig. 2. The string should be wound tightly and the tension should be even; twelve winds of string are all that are necessary for initial practice. The loose end of the string should be firmly tied to the small screw-eye at the bottom of the frame after winding. It should be obvious that only a very simple form of weaving can be done on the loom illustrated.

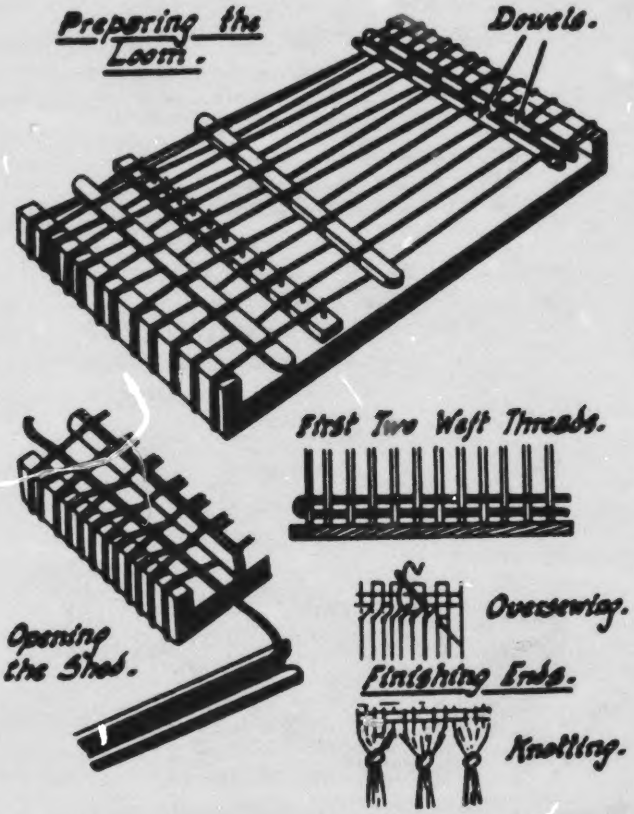

Preparing the Loom.
Dowels.
First Two Weft Threads.
Opening the Shed.
Oversewing.
Finishing Ends.
Knotting.

Fig. 2. SETTING UP THE PRACTICE LOOM

The Warp: This term is common to all forms of weaving and it is used to describe the fixed strings or threads described above, which are the foundation of the fabric. Various means are used with the different types of loom for holding the warp firmly and keeping the strands seperate. In the simple loom described, this can be done by fitting two dowel rods across the frame over and under alternate threads of the warp. The rods are illustrated in Fig. 2, and it will be seen that the tension can be easily increased by drawing the two rods closer together. The rods should be attached to the back end of the frame, as shown in the illustration. Thus the warp is set up on the frame of this loom. Variations of setting up the warp will be explained in detail when describing other types of looms.

The Weft: This is another term common to all forms of weaving, which is used to describe the long thread woven through the warp (fixed threads). For the purpose of practice on this simple loom the weft material can be cotton rug yarn. The material woven by passing the weft thread through the warp is known as the "web."

So now we have the three main items of weaving. The loom (the simple framework) on which the warp threads are set up, and the weft (the thread woven into the warp to form the web.) Before commencing weaving it is necessary to have three more pieces of equipment. These are a shed stick, a shuttle, and a reed.

The Shed Stick: This is shown in the illustration (Fig. 1), and it is used to seperate the warp threads. It is a narrow piece of thin wood with rounded ends, which is passed through the warp under and over alternate threads. Two shed sticks are used in this form of weaving, and it will be seen from the illustration that they are passed through the warp threads in alternate order. When weaving is being done, one of the shed sticks is turned on edge to seperate the warp threads for passage of the weft.

The Shuttle: This is another basic item of equipment used in all forms of weaving. There are many different types of shuttles used with different looms, but for the purpose of explaining the fundamentals of weaving the shuttle described and illustrated (Fig. 1) is a narrow thin piece of wood with a U-shaped notch cut at each end. Like the other equipment described, the shuttle can quite easily be made at home.

The Reed: Also known as the "comb" is shown in the illustration (Fig. 1) in the form of a flat piece of wood with nails hammered into it, and for the purpose of this explanation, thirteen nails are shown and spaced to separate the warp threads. (The spaces between are known as "Dents"). This piece of equipment is not attached to the loom illustrated, and it may be different in shape and form for use with some of the other looms described later in this book. The reed is used to beat up the "pick": (The pick is the term used to describe the weft threads as they are passed through the warp) to make a firm web (the woven material).

Weaving on the simple loom: After setting up the warp on the simple loom, the rods should be fastened in place, and one of the shed sticks inserted through the warp threads over and under in alternate order. The weft material of coarse yarn should be wound round the shuttle between the U-shaped notches, with the end of the material free, and the reed should be put in place behind the first shed stick as illustrated in Fig. 2. Darn the shuttle through the warp threads from right to left, under and over alternate threads, a short distance from the front of the loom, leaving two or three inches of the yarn hanging over on the right of the weft. With the right hand hold the yarn where it meets the first warp thread on the right, and darn the shuttle back through the warp threads—this time from left to right—under and over alternate threads in opposite order to those first worked. Hold the left edge of weft and warp and pull the yarn straight, but not too tight. Bring the reed forward, with the nails between the warp threads, and press it firmly against the darned pick, and your two rows of yarn should look like those in the illustration (Fig. 2). The odd end of the yarn is afterwards darned in the web.

To continue, turn the reed down and bring the shed stick forward to a distance of four or five inches from the pick, and turn it on its side (this is also shown in the illustration—Fig. 2). The shed stick seperates the warp threads and the space thus formed in front of the pick (the weft threads already woven) permits easy passage of the loaded shuttle. This space is known in weaving as the "shed," and the term is common to all forms of weaving done on any kind of loom. Before passing the shuttle through the shed, insert the second stick, flat on its side, through the warp behind the reed, and ensure that it is worked under and over alternate threads to those seperated by the first shed stick. Pass the shuttle through the shed from right to left to the third warp strand of yarn; pull the yarn firm, remove the first shed stick, and turn the reed up to bring it forward to beat up the pick.

Continue in the same way, repeating the sequence of actions. After beating up the pick, turn down the reed and bring the shed stick forward, turning it on edge to open the shed; place the other shed stick in position through the warp (always in alternate order to the first one for this simple weave), and pass the shuttle back through the shed alternately from left to right. As the web progresses it may be observed that it is drawn in and is not so wide as the warp threads. This loss of width is due to the compression of the warp in weaving, and this can be largely avoided by adjusting the tension of the weft strands before they are beaten down. The edges should be watched as the work progresses, and the tension on the weft should be even throughout the work. This is not always easy for the beginner to do, but if it is carefully watched in the early stages, and the reason for the looseness fully understood, it should be a simple matter to overcome the fault with practice. It may be found that the tension on part of a weft thread is greater than that of the rest, causing the weft to curve. The tension, of course, should always be even throughout the work and tightness or looseness of the weft adjusted immediately it is observed. The pressure on the reed should also be even throughout the work, and after a little practice on this very simple loom, the beginner will soon find how to regulate the tension of the warp threads, and beat up the pick evenly to form the web with firm straight edges.

Continue weaving the practice piece on the simple loom, as described above, to within four or five inches of the end of the loom. The web formed by passing alternate weft threads through alternate warp threads is described as plain weaving or "tabby" weave. There are many variations which will be explained later in the book. The ends of woven fabric may be finished in several different ways, and these are best done on the loom rather than cutting the warp threads and finishing the ends off the loom. The ends may be oversewn with strong yarns as illustrated in Fig. 2, and the stitches should be sewn through each of the weft and warp threads, and fastened off firmly, or the ends of the warp threads may be knotted to form a fringe—this is also illustrated in Fig. 2—when securing the ends of the web, the woven material should be removed from the loom, by cutting through the warp threads.

It may be found in working on larger looms that there may be some slight variations of the usages and methods described; for instance, shed sticks are used slightly differently in larger looms—the object at this stage is to clarify the preliminary instructions.

The information given above has been written in very simple style to give the veriest beginner a working knowledge of the elementary principles of hand-loom weaving, and includes most of the technical terms used in weaving. But it should not be assumed that the simple loom described is only suitable for practice—it can be used to weave some very good small articles.

To modify the practice loom, screw four cup hooks into the ends of the frame at the top, as shown in illustration Fig. 4. Position the cup hooks so that the closed sides of them face inside the loom. Cut two pieces of dowel rod to rest in the cup hooks which may be bent a little to prevent the rods falling out. Drill a small hole through both ends of each rod and insert a short piece of strong wire through the holes at each side of the frame at both ends; hammer a small nail into position, as shown in the illustration.

All the other items used with the simple practice loom will be required for use with this loom—the cross rods (dowel rods), the reed, shed-sticks, and the shuttle. For practice, the worker can again use string for the warp, which for this loom is attached to the to the two roller rods. To set up the loom, place the two dowel rods in the cup hooks and tie a piece of string to the ends of the dowel rods, as shown in the illustration Fig. 4, to keep them in place while setting up. The warp threads should be about six inches longer than double the length of the piece of material which is to woven. The string should be doubled and looped over the warp rod at the back of the frame, as shown in the illustration Fig. 4. Pass the end of the string through the loop, which should be closed very tightly to prevent the warp slipping round the dowel in a later stage of the work. Fasten the required number of warp threads to the warp dowel, then fasten the ends of the warp strings to the dowel rod at the front of the loom, and fasten them very tightly. It will obviously be necessary to have the strands all exactly the same length to maintain even tension of the warp.

After fastening the ends of the warp strands to the rod at the front of the loom, wind the back roller rod round clock-wise, as shown in the illustration, to tighten the warp, and finish with the pieces of wire at the end of the back dowel lodged against the small nails in the side of the loom. Before inserting the cross rods and trying them to the frame, ensure that the tension on each warp string is even; if any are loose it will affect the firm texture of the weaving. Work the cross rods through the warp, as previously described, and fasten them to the frame.

Insert one of the shed-sticks over and under alternate warp strands if a plain tabby weave is to be worked, or under and over two strands at a time if a twill weave is to be done. As explained above, weave in the same way by passing the shuttle backwards and forwards through the shed, beating up each pick as it is formed,

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and when several inches of the web have been completed release the tension on the warp rod at the back of the frame and tighten up and twist the warp rod at the front of the frame. Lock the dowel rods in position, and before commencing the next stage of the work make any adjustments to the cross rods necessary to take up any slackness of the warp. This simple modification of the practice loom demonstrates how the length of the material can be increased beyond that of the length of the loom.

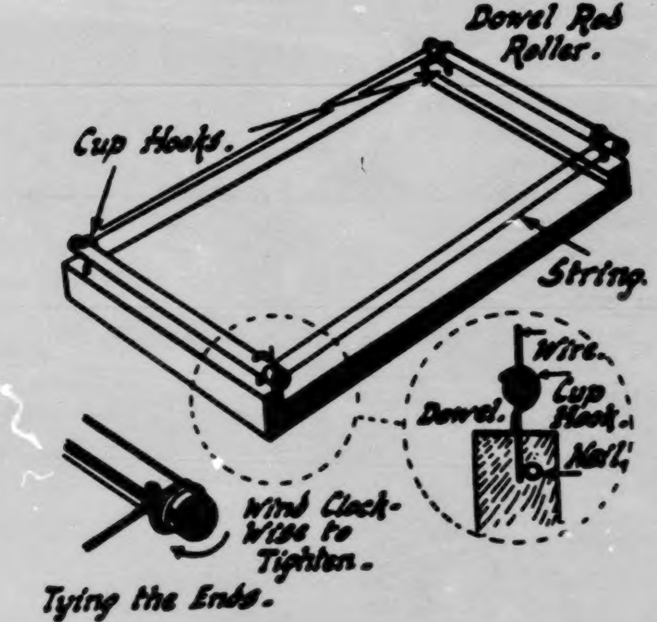

Dowel Rod Roller.
Cup Hooks.
String.
Wire.
Cup Hook.
Dowel.
Nail.
Wind Clock-Wise to Tighten.
Tying the Ends.

Fig. 4. MODIFYING THE PRACTICE LOOM

Looms of more advanced design than the simple practice loom—with the roller modification—previously described, takes the learner beyond the beginner stage into the realm of Table Looms. The structure of table looms may vary according to the ideas of individual manufacturers, but in principle their actions are similar. The table loom illustrated in Fig. 5 is a step forward from the practice loom pictured in previous illustrations, but it has several points of similarity; it will be remembered that the "loom" is the frame upon which the weaving is done. In our first loom the warp was set up by winding string round the wood frame—in the table loom (Fig. 5) it will be seen that the warp is stretched between two rollers similarly positioned and controlled to the dowel-rod rollers of out first loom, that is, one roller at each end of the loom, which is wound tight, or freed, by adjusting control pins or pieces of wire held in place by nails or pegs in the side of the frame. Our simple board, with a piece of wood attached each end, has developed into a box-like frame with rounded slots cut in the sides to hold the rollers in position (instead of the cup-hooks), and the wire peg, or nail inserted in the side of the frame can be placed in more than one position to adjust the tension of the warp when rolling off the web. The shed-sticks used with our last model and the reed have been combined in the form of a heddle-reed, which is included in the illustration (Fig. 5). The heddle-reed seperates the warp threads to form the shed through which the shuttle is passed (this is only suitable for tabby weave). The cross-rods remain, but in this loom they are narrow flat pieces of wood (also known as "shed-sticks") and as before they are positioned at the end of the frame.

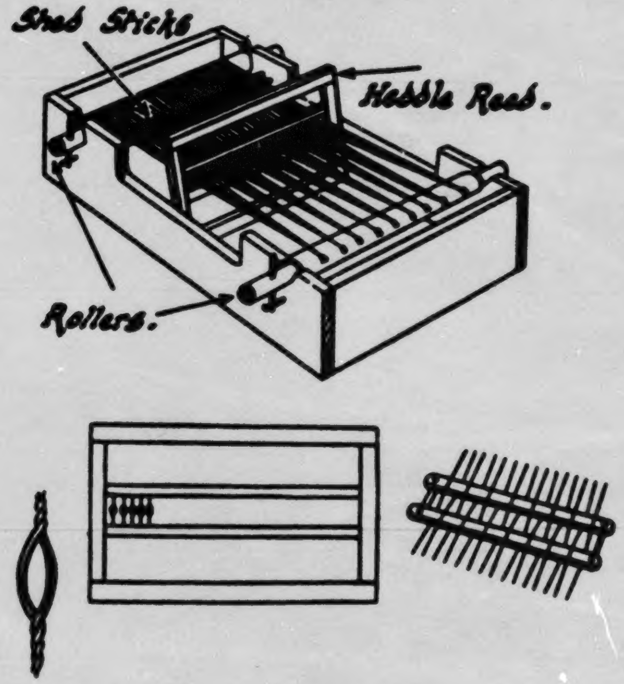


Fig. 5. A TABLE LOOM

A table loom such as the one illustrated, could quite easily be made at home, but if this is done care should be taken to form the joints of the frame carefully so that it is rigid and the ends square with the sides. A broom-handle could be pressed into service for the rollers, and the cross-rods could be made from builder's laths; a strip of canvas should be firmly tacked to each roller to help to secure the ends of the warp. Two dowel rods should be attached to the canvas of each roller, as illustrated. A home-made loom of this type would be quite suitable for practicing weaving, but if the craft is to be made the subject of a commercial venture the hand-weaver should purchase a craftsman-made loom. Some very attractive and useful articles can be woven on this table loom— in which the length is not controlled by the length of the framework, because of the rollers; but, of course, the width of the web is slightly less than the width of the loom. The heddle-reed can also be made at home. It consists of a light wooden frame which should be strong and rigid, upon which is strung fine wire twisted as shown in Fig. 5, to form a row of holes. Additional heddle-reeds can be made for use with this loom for weaving some of the more intricate patterns. In setting up the loom, some of the warp threads are passed through the holes in the heddles. It will be observed that the loose pieces of equipment prominent in the practice loom are incorporated in the table loom. The only loose part is the shuttle.

The shuttle can be the same shape as the one previously described and illustrated, but it should be long enough to pass through the shed, or roller shuttle may be used with this type of loom. The roller, or hand shuttle, is illustrated in Fig. 6. The advantage of this type of shuttle is that it can be thrown through the open shed, making the work very much easier and quicker. The best roller shuttles are made of hardwood with a very smooth finish. Sizes vary, but usually they are six to eight inches long; these shuttles are shaped like a boat, and carry a bobbin in a hollow center. The bobbin freely rotates on its spindle and the thread is passed through a hole in the side of the shuttle; the bobbin is held in the body of the shuttle by means of a spring which in some hand shuttles can be regulated to adjust the tension of the weft. Shuttles used in weaving fine yarns may not be fitted with rollers at the bottom, the smoothness and shape of them being relied on to pass freely over the delicate threads; but shuttles used in weaving coarser yarns may be fitted with rollers to assist them in gliding over the lower warp strands when the shed is open. In action the hand shuttle is held with the point inserted in the open shed and is flicked to glide along the threads to be caught in the other hand. There is quite a knack in manipulating this type of shuttle, and after practice the worker will find that not only can the action of weaving be speeded up, but the quality of the web can be improved by controlling the weft at an even tension best suited to the yarn used. It may be considered that the use of a hand or roller shuttle is not necessary with such a narrow loom as the one described, but it will be found as the weaver progresses beyond the learner stage, that the quality of weaving with this type of shuttle is much superior to the method previously described. The roller shuttle will again be referred to in later instructions.

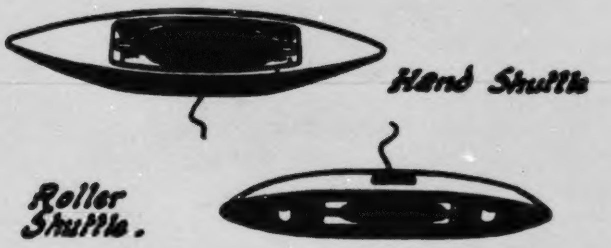


Fig. 6. SHUTTLES

Warping: With our simple practice loom the warp was set up by winding string round the body of the loom. To set up the table loom a different method of setting up is adopted, and this is known as "warping". Detailed information about warping is given later in these instructions describing the use of warping boards and warping mills, but for the purpose of explaining how to prepare a warp for the table loom described, and to avoid confusing the learner-weaver, only a very simple method of preparing the warp is described at this stage. Before warping it will be necessary to estimate the warp, and the amount of yarn required, for the warp of a particular object will vary according to the type of yarn being used—wool, linen, cotton and silk, and synthetic yarns of different weights and qualities will obviously vary in thickness, and to estimate the number of threads of the warp it will be necessary to determine the number of strands of whatever yarn is used to the inch. For the purpose of clarifying this explanation, the weaving of a simple scarf is described as being the first practice piece made on the table loom.

The width of the scarf to to be 9 inches, and the length 40 inches (not including the length of the fringe); it is to be made with 2-ply wool and one colour only used for the warp.

As previously explained, the spacings between the warp threads may vary according to individual requirements, but for our scarf of 2-ply wool we will count 12 threads to the inch across the warp. Therefore, if the scarf is to 9 inches wide and there are 12 threads to the inch, the number of threads required for the warp will be 9 x 12, which equals 108 threads; and extra thread should be added each side for the selvedge, and these two additional threads bring the total up to 110 in the warp. To determine the length of the warp the amount of loom wastage and shrinkage should be added to the length of the scarf (although described as wastage, not all is waste as some will be taken up by the knotted fringe at each end of the scarf). Loom wastage may vary according to the construction of the loom, and shrinkage also may vary according to the yarn material beind used. The length of shrinkage and wastage for this scarf is estimated at 11 inches. Therefore, if the scarf is to be 40 inches long and the wastage is estimated at 11 inches, the total length of the warp will be 40 x 11, which is 51 inches. A simple warping board, used for preparing the warp, is illustrated in Fig. 7. It is a flat piece of wood with holes drilled in it; the dimensions of the board and the distance between the holes are shown in the illustration (Fig. 7). Pegs are fitted into the holes, and although they should fit tightly for winding the warp, they should be removable in order to adjust them for winding warps of different lengths. By adjusting the number and groupings of the pegs, warps of almost any length for the table loom described, can be prepared. The importance of sturdiness in the warping board cannot be overstressed. The pegs should be substantial in make and they should firmly fit into their holes—the strain of numerous threads wound round the pegs can be considerable.

To prepare the warping board for a 51 inch warp (the length of the scarf plus an allowance for wastage), set the pegs in the board as illustrated in Fig. 7. Only half the board is used, and only seven pegs are set in holes in the positions shown in the illustration. To clarify these instructions the pegs have been numbered from 1 to 7. The peg-holes in this board are three inches apart, and if those used in Fig. 7 are counted it will be noted that there are 17 three-inch spaces between peg No. 1 and peg No. 7. Thus the length of the warp is regulated at 51 inches. (It will be obvious that by changing the positions of the pegs in the holes longer or shorter warps can be prepared on the board.)

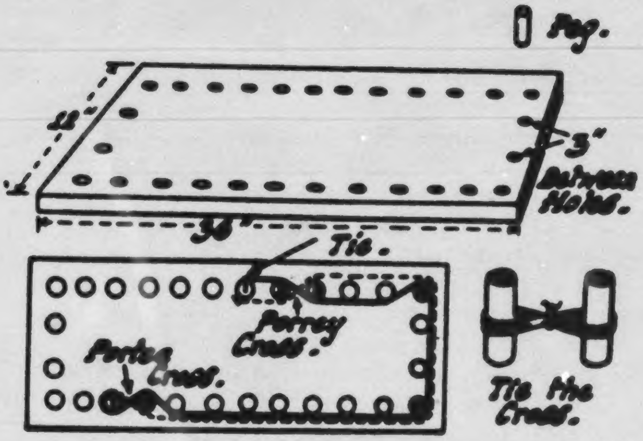


Fig. 7. A WARPING BOARD

After positioning the pegs and setting them firmly in their holes to take the strain of the threads of yarn, the end of the yarn, the end of the yarn should be tied to peg No. 1. When firmly tied it should be taken along to peg No. 2 which passes, and should cross outside this peg to the inside of peg No. 3. Continuing round the board to the right the yarn should be brought round the outside of peg No. 4 then along the end of the board round the outside of peg No. 5. From peg No. 5 the yarn should be taken round the inside of peg No. 6, then round the outside of peg No. 7. This completes the winding of the first warp thread.

To wind the second warp thread on the numbered pegs, keep the tension on the yarn and bring it round peg No. 7. From peg No. 7 pass the yarn round the outside of peg No. 6 (this is in opposite order to the first wind). Continue round the outside of pegs No. 4 and 5 at the corners, outside peg No. 3, over the first thread and inside peg No. 2 to peg No.1 which the yarn is wound round to commence the third warp thread. Continue winding the yarn round the numbered pegs in the same order until 51 threads are wound on. Keep the tension on the yarn even all through the winding process; this is very important, and if care is taken at this stage to keep the tension even much trouble will be saved when the warp is on the loom. To secure the warp, tie the yarn at the end of the 51st wind firmly to peg No. 7.

Before removing the warp from the board the crosses should be tied. These crosses are identified in the illustration (Fig. 7) by their names; the crossed threads between pegs 2 and 3 form the "Porrey" cross, and the crossed threads between pegs 6 and 7 form the "Portee" cross. To tie the crosses, pass a piece of cord through the threads at each side of the crosses (as illustrated in Fig. 7) and tie the cord. Of the two crosses, the porrey is the most important. After tying the crosses, the warp can be removed from the warping board. There is a certain way to remove the warp from the board to prevent the warp threads becoming tangled. To remove the warp, ease it off the pegs (if it is very tight remove the corner pegs—Nos. 4 and 5); hold the warp with the left hand at the portee cross (as shown in the illustration—Fig. 8) and place the right hand through the looped threads at the top of the warp; when doing this be careful not to disturb the threads more than can be avoided. Turn the right hand down to grasp the warp under the portee cross and draw the threads through the first loop, thus forming a second loop. Repeat this process by again placing the right hand through the second loop, grasping the warp threads and pulling them through the second loop to form a third loop and continue to the end of the warp. This is known as "Chaining" and is similar to the simple crochet stitch of that name.

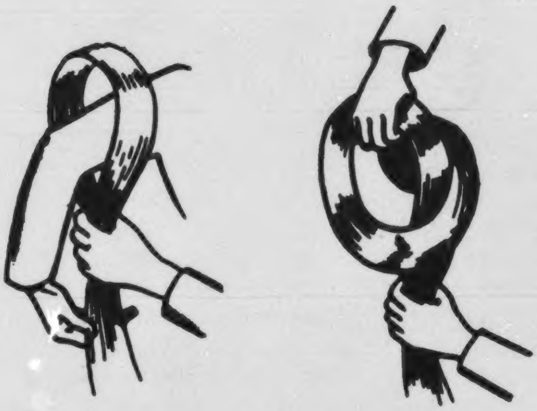


Fig. 8. CHAINING THE WARP

It is suggested that the beginner should practice several warps until the process is thoroughly understood before preparing the warp for the scarf—the practice warps can be prepared with string, and not only should practice be carried out in preparing the warp on the warping board, but also in chaining the warp, and releasing the chain. When the end of the warp at the last chain is pulled it should slide freely from the loop above it. It may be found—before experience is gained in practice—that although the worker was careful in forming the chain not to disturb the threads in the warp they may be inadvertently twisted and the chain is locked. If this happens, the threads should not be tugged to release them; tugging will only tighten the lock in the chain, and the only way to release it is to pass the other end of the chain through the first loop, unchaining the warp and forming the chain afresh. Time spent in practice at this stage is never wasted.

Setting up the Loom: After preparing a sound warp for the scarf it is ready for "beaming". Beaming is the term used to describe the process of fitting the warp to the loom. There are several ways of doing this which may vary considerably according to the type and manufacturer of the loom, and for the table loom mentioned in this chapter a simplified form of beaming is described.

First pass the two shed-sticks through the end of the warp—one each side of the porrey cross—as illustrated in Fig.9. Spread the warp between the shed-sticks thread by thread in order, to a width of 11 inches (the width of the scarf), and tie the ends of the shed-sticks to the front roller, which should then be placed in the slots at the front of the frame. Next clamp the heddle-reed to the frame (illustrated in Fig. 9).

The next part of the work is best done by two persons; one at the back of the loom and the other at the front. The person at the back of the loom should have a crochet hook to pass through the holes in the heddle-reed for the person at the front of the loom to hook the looped threads on. After each looped thread is hooked on the crochet hook it should be drawn back through the holes in the heddle-reed and passed over one of the dowel rods from the back roller of the loom. The hooking and looping should commence in the center of the spread warp, working a central looped thread of the warp through a central hole in the heddle-reed, and after passing the looped thread through the hole in the heddle-reed (this hole is known as a "dent") and passing the loop over the dowel rod, the remaining threads should be passed through alternate dents in a definite order. After securing the first thread, take the thread next to it and pass that one through the next dent but one from the first one and loop it over the dowel rod.

The third thread treated should be the next thread on the other side of the first thread, and the work of threading should proceed in the same order—that is from the center working alternately from side to side. It is of the greatest importance to take care with this part of the work not to get the threads tangled and crossed.

After passing all the threads of the warp through alternate dents in the heddle-reed and looping them over the dowel rod, the rod should be secured to the canvas of the back roller and firmly tied, as illustrated in Fig. 9. The next thing to do is to unchain the warp, and holding it at the end, ensure that all the threads are firmly fastened to the beam at the back of the loom and that the tension is even throughout the warp.

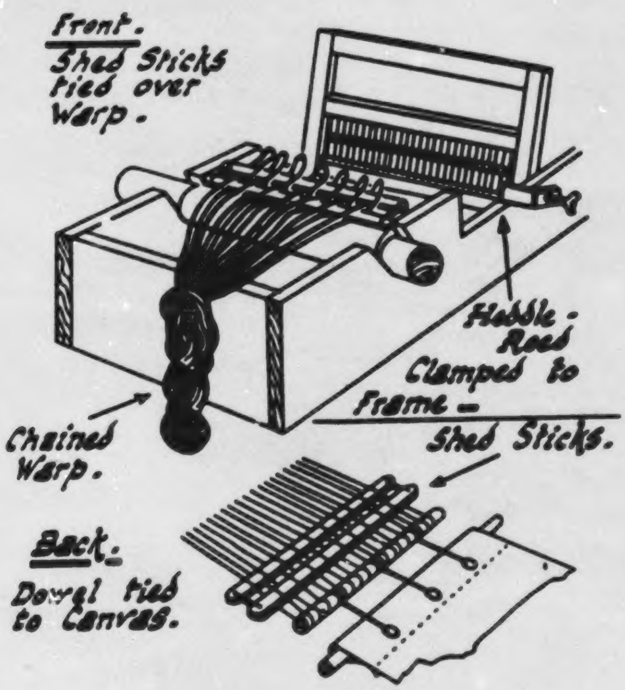

Front.
Shed Sticks tied over Warp.
Heddle-Reed Clamped to Frame.
Chained Warp.
Shed Sticks.
Back.
Dowel tied to Canvas.

Fig. 9. PREPARING THE TABLE LOOM

Still holding the warp taut, commence turning the roller back in its groove. As the canvas is taken up, strips of stout brown paper slightly wider than the warp should be inserted between the roller and the warp. Keep the tension on the warp and when about 10 inches of the warp is left in front of the clamped heddle-reed lock the back roller. Release the shed-sticks from the front roller and insert them through the warp behind the heddle-reed under and over to form a cross in the warp between them, as illustrated in Fig. 9. After doing this, cut through the loops of the warp threads at the front of the loom, and wind the back roller to draw the cut threads through the dents in the heddle-reed, until they hang from the back roller, as shown in Fig. 10. At this stage the warp is now ready for entering, which simply means that the threads must once again be passed through the dents of the heddle-reed in their proper order and this time back to front.

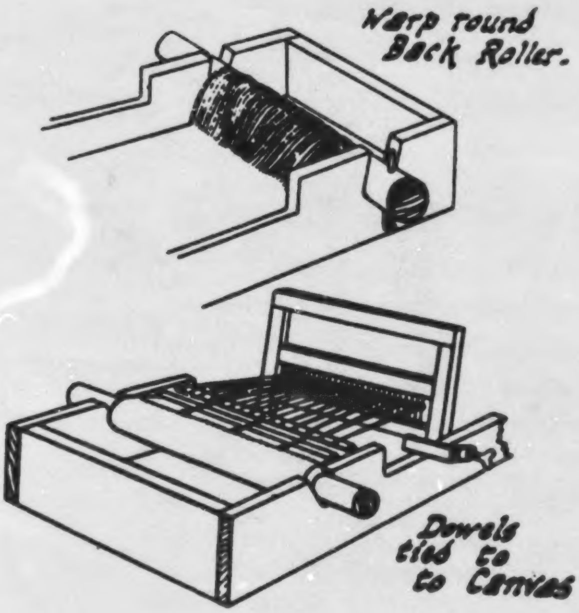


Fig. 10. ENTERING THE WARP

It is advisable for two persons to do the entering or threading, and the person at the front of the loom should have a crochet hook. Commence again at the center of the warp; the person at the front of the loom should put the crochet hook through the center dent of the heddle-reed, and the person working at the back of the loom should bend the end of the center thread and fasten it over the hook, which is then drawn through the dent. The second thread of the pair should be passed through the space between the dents; this threading and spacing should be carefully done not to cross any of the threads. Work from both sides of the center of the wrap in alternate order and when 12 threads have been passed through the heddle-reed, secure them to the dowel removed from the canvas of the front roller. The threads should be tied to the dowel in the manner illustrated in Fig. 10, and the work of entering should be continued, trying each group of 12 threads until the last threads at the sides of the warp are reached—after trying eight groups of 12 strands each to the dowel rod; the last tie each side should consist of six threads each, this making a total of 110 warp threads in all, including the two extra each side allowed for the selvedge.

When tying has been completed the heddle-reed may be released from the clamps and moved to the back of the loom, and the dowel rod should be firmly tied to the rodded canvas (see Fig. 10). Make any adjustments necessary to the ties to evenly tension the warp, unlock the back roller, and wind the front roller round (with the canvas rolled over the top) to prepare the loom behind the heddle-reed, as in Fig. 10. The loom is now ready to receive the weft. By raising and lowering the heddle-reed it will be found that the shed is opened for passage of the shuttle. Lowering the heddle-reed presses down the alternate strands threaded through the dents below the threads between the dents, and raising it reverses the action, so that if the heddle-reed is alternately lowered and raised the shed is opened, in the correct order passage of the weft, to form tatby weave. The scarf is woven in the same way as on the simple practice loom previously described, by working the shuttle across the shed, rolling the web back as it is completed, and knotting a fringe at the ends. The only difference is that between each pick the heddle-reed is brought back on the warp to beat up the pick. Colour schemes and patterns can be worked out on squared paper as is also the method of winding the bobbin of the roller shuttle, if it is used at this stage.

Dyeing Wool: Wool is obtainable in three different conditions: these are "In grease" wool, "washed" wool and "scoured" wool. "In grease" wool is so called because it is supplied in its original state of impurity and has not been washed to remove the grease. "Washed" wool, as its name implies, has been washed to render it clean, and has had some of the grease removed. "Scoured" wool is wool that has been made perfectly clean with all grease and impurities removed.

Before commencing to dye wool, it is important to make certain that your wool is free from grease, and if "in grease" wool or "washed" wool is to be dyed, it should first be washed to free it from all traces of grease. The wool is washed in water to which ammonia and soft soap are added in the following proportions, which are given for a ten-gallon bath: to ten gallons of water add 6 oz. of ammonia and 3 oz. of soft soap.

After mixing, heat the water to a temperature of not more than 140 deg. Fahrenheit. Care should be taken in washing wool not to felt it; the water should not be too hot, and while washing it the wool should be squeezed as little as possible. When the wool has been thoroughly washed and is free from grease, dyeing and mordanting should be proceeded with. There are several methods of dyeing wool according to the nature of the dye; these are given as under:

(1) Some dyes do not require mordanting and the wool can be heated direct in the dye.
(2) The wool can be heated with the mordant and dyed in the same bath.
(3) The wool is separately mordanted, then dyed and after dyeing is mordanted again. This method ensures that the dyes will be extremely fast.
(4) With this method the wool is heated first with the dye and when it has absorbed colour the mordant is added to the bath to fix the colour.

Mordanting should be carried out as follows, there being some slight difference in the method of using two mordants:

Alum: Fill your bath with sufficient water to cover the wool, then, before placing the wool in the bath, add alum in the proportion of $\frac{1}{4}$ lb. of alum to every 1 lb. of wool being dyed. When the alum has dissolved in the water, the wool should be put in. Heat the bath and bring the water to a temperature of 140°F., stirring occasionally, and after one hour at this temperature take out the wool and wrap it in a cloth while it is still damp. After wrapping the wool

TABLE I. SIMPLE DYEING CHART FOR WOOL

Colour	Quantity of wool	Dyestuff	Mordant	Time and Method	Time of year	Remarks
Brown	3 lbs.	Walnuts	None	Boil shells and cool. Enter wool. Heat for 1 hour at 140° F.	When nuts are ripe	
Yellow	3 lbs.	6 lbs. fresh birch leaves	3/4 lb. Alum	Boil leaves for 1 hour. Enter wool. Heat 140° for 1½ hours	Summer	
Lemon	3 lbs.	Mignonette	3/4 lb. Alum	Boil for 3 hours. Enter wool Heat for 1 hour at 140°	Summer	Use whole plant. Gives very fast colour
Yellowy Green	3 lbs.	Nettles	3/4 lb. Alum	Boil nettles for 1 hour. Enter wool. Heat for 1½ hours at 140°	During May	
Crimson	3 lbs.	4½ oz. Cochineal 3 dessert- common salt	3/4 lb. Alum 4½ oz. cream of tartar	Bring to 140°. Simmer for 1 hour. Enter wool. Keep at temperature of 140° for 2 hours	All the year round	Many shades can be obtained by varying the quantities
Rust	3 lbs.	16 oz. Madder	As above	Bring to 140°. Simmer for 20 mins. Enter wool. Continue to simmer for 1 hour	All the year round	
Grey Blue	3 lbs.	3 lbs. crushed sloe berries	None	Boil berries for 1 hour. Enter wool and heat for 1 hour at 140° F.	Autumn	Place berries in a muslin bag to boil

it should be left for two or three days, and before dyeing should be lightly washed to rid it of superfluous morcant.

Chrome: To mix a chrome mordant, fill a bath with sufficient water to cover the amount of wool to be treated, and add the water before placing the wool in the bath 3 oz. of chrome to 1 lb. of wool. Allow the chrome to dissolve in the water, place the wool in the bath, bring the water to a temperature of 140°F. and maintain it at this point for three-quarters of an hour.

A dyeing chart for wool, which gives full information about colours, quantities to be dyed, description of the dyestuff, mordants, and the time for dyeing is given in Table 1.

It is important in all stages of preparation of mordant and dyeing wool not to allow the temperature of the bath to exceed 140°F. or the material may be thickened and damaged.

Silk: The dyeing of silk, providing information of colours, quantities, dyestuffs, etc. is given in Table 2.

Silk is obtainable for hand weaving in two kinds, one of which is waste silk (which is generally known as Spun silk), the other variety is raw silk. Raw silk is coated with a gummy substance which has to be removed before it can be dyed. To clean raw silk place it in a canvas bag, which should be tied at the mouth, and heat it in a strong solution of soap for several hours until all the gummed coating is removed.

Silks for hand-loom weaving can be dyed in the same way as wool, but lower temperatures are used in the dyeing of silk than used in dyeing wool. In some cases soaking in a cold solution of the mordant is sufficient preparation of the silk. For treating bright coloured silks an Alum mordant should be used; if it is necessary to brighten the colours, tin mordant should be used. When black dyes are to be used an Iron mordant is required.

To prepare Alum mordant for silk, dissolve 3 lbs. of Alum and 3 oz. of chalk in a gallon of water. Add 2 lbs. of white acetate of lead. Stir the mixture occasionally and allow it to remain for about thirty-six hours. After the final stirring let the mixture

TABLE 2. SIMPLE DYEING CHART FOR SILK

Colour	Quantity of silk	Dyestuff	Mordant	Time and Method	Time of year	Remarks
Orange	1 lb.	½ lb. Madder 2 oz. Flavin 1 oz. Tin	Alum Acetate	Enter Tin in a cold bath. Mix Flavin and Madder to paste. Add to bath and bring to boil. Enter silk and heat 10 mins. at 140° F. Wash in soap.	All the year round	
Black	1 lb.	6 oz. Logwood 3/4 oz. Flavin 1 oz. Iron	Alum Acetate	Mix all dyestuffs together in bath. Enter silk and heat ½ hour. Wash thoroughly.	All the year round	Put dyestuffs in muslin bag to boil.
Grey	1 lb.	A quantity of Bracken tips	1 oz. Iron 2 oz. Cream Tartar	Boil quantity of young Bracken tips for ½ hour. Strain. Enter silk and heat for ½ hour	When Bracken tips available	
Red	1 lb.	5 oz. Cochineal 1 oz. Tin	1 oz. Tannic Acid	Dissolve 1 oz. Tannic acid in hot water. Enter silk and leave for 24 hours. Rinse well. In clean bath put 4 oz. cochineal. Enter silk and heat till blue colour develops. Lift silk. Add 1 oz. cochineal and 1 oz. tim. Re-enter silk. Heat well. Wash in soap.	All the year round	While silk is in tannic acid bath stir from time to time.
Brown	1 lb.	Quantity of lichen according to shade required	Alum Acetate	Put into dye bath. Quantity of lichen. Add 1 tsp. acetic acid. Enten silk. Heat for 1 to 3 hours at 140° F.	When lichen obtainable	Vary the quantity of lichen to obtain different shades of brown.

stand for twelve hours and decant the clear liquor. To the residue, add two gallons of water and leave it twelve hours. Decant it and add the clear liquor to the first decanted. Stir and bottle the mixture.

When using the mixture, add two parts of it to one of water and work the silk into the solution. Leave it in the mixture for two hours, then take it out and allow to dry. After drying, wash it well in clean water before dyeing.

Cotton: Cotton is difficult to dye unless it has first been mercerised. Cotton is always best dyed with chemical dyes, and it should be boiled in Alum mordant, then boiled in dye. Before commencing mordanting and dyeing cotton, it should be boiled for several hours to completely rid it of all impurities.

Dark coloured cottons should be boiled in plain water. For boiling light coloured cottons carbonate of soda should be added to the extent of 5 per cent (by weight) of the quantity of water used, or caustic soda may be used, in which case the quantity should be only 2 per cent.

Brown cotton—when dyeing use a chrome mordant; boil the cotton first in the dye, then boil it in the chrome solution for a short time. For treating pale and light coloured cotton, use a tannic acid mordant, adding 10 per cent of tannic acid by volume to the water.

In the last-named case, the bath may be hot or cold, but if hot, the temperature should not exceed 140°Fahrenheit. Work the cotton in the mordanting solution, then leave it to soak for twelve hours. After soaking, wring it out and wash it.

A dyeing chart for cotton, showing colours, dyestuffs, quantities, mordants, time, etc. is in Tables 3 and 4 (Linen is dyed in the same way as cotton).

Plants for Dye Colours: Plants for making red dyes are: Birch, Common Sorrel, White Madder, Potentil and Gromwell.

Plants for making blue dyes are: Elder, Privet, Sloe, Woad, and Yellow Iris.

Plants for making yellow dyes are: Ash, Barberry, Birch leaves, Gorse, Bog Myrtle, Bramble, Broom, Crab-apple, Marsh Marigold, Nettle, Pear and Plum.

TABLE 3. SIMPLE DYEING CHART FOR COTTON

Colour	Quantity of Cotton	Dyestuff	Mordant	Time and Method	Time of year	Remarks
Red	1 lb.	12 ozs. Madder	Boil out in soda, wash and dry. Steep overnight in a hot bath of 1½ oz. tannic acid. Dry, then steep in cold solution of ¼ lb. alum and ½ oz. chalk dry. Add 2 ozs. more alum and steep as before. Wash and dry.	Add Madder to cold bath. Enter cotton and bring to boil in 1 hour. Rinse and re-dye as above. Rinse in warm bath with 2 ozs. soap. Wash and dry.	Any time of year	All cotton should be mercerised before dyeing. See text.
Yellow	1 lb.	1½ oz. Flavin	Steep overnight in hot bath with 1½ oz. tannic acid. Wring dry. Work in bath containing ¼ lb. alum., ½ oz chalk (dry). Pass through weak chloride of lime. Dry. Return to alum bath and repeat process. Wash well.	Add Flavin to cold bath. Bring to boil and dye slowly.	Any time of year	4 ozs. Galls may be used in place of Tannic Acid.

TABLE 4 (continued from Table 3). SIMPLE DYEING CHART FOR COTTON

Colour	Quantity of cotton	Dyestuff	Mordant	Time and Method	Time of year	Remarks
Brown	2 lbs.	12 ozs. Fustic	Put 2 ozs. cutch and 1 oz. chrome in separate baths	Enter cotton in cutch bath. Boil for 20 mins. Wring. Boil 10 mins. in chrome bath. Add 6 ozs. of fustic to cutch bath. Enter cotton. Repeat process till shade required is obtained.	Any time of year	Colour may be darkened by adding 1 drachm of copper sulphate.
Black	2 lbs.	12 ozs. Logwood 2½ ozs. Madder 8 ozs. Fustic	Wash cotton, steep overnight in hot bath containing 2 ozs. tannic acid. Wring out and work in 1¼ oz. soda bath at temperature of 50° to 60° C. Wring and work in cold bath containing 1¼ oz. copper as for ½ hour. Return to soda bath for ¾ hour.	Mix dyestuffs in cold bath. Enter cotton and bring to boiling point. Boil for ½ hour. Pass through warm solution of 1 oz. chrome. Wash and work through warm bath containing soap.	Any time of year	To obtain Greys. Dye with 1 to 5 per cent. of logwood after mordanting in iron.

Plants for brown dyes are: Hop, Onion, Larch, Oak, Walnut, and Dulse Seaweed.

Plants for purple dyes are: Dandelion, Deadly Nightshade, Dock and Meadowsweet, and it must be recognised that many of the plants included in these lists are poisonous. They must be handled carefully and should be safely stored to prevent any damage or danger of accidents.

In addition to the plants listed above, dyes may be made from lichen. Many ordinary lichens make extremely good fast dyes of shades of brown, and they are largely used in the Highlands and Western Ireland. For dyeing materials brown, no mordant is needed with lichen dyes and the colours are the fastest known in the vegetable group. The lichens are collected in the summer, in July and August, and after drying in the sun are put into a bath containing sufficient water to cover them, and the water is then boiled.

After the lichen dye bath is cool, cotton may be immersed in the liquid and then boiled until the shade of brown required is obtained.

The information given above is sufficient to enable the home weaver to dye materials. There are, of course, other dyes and mordants, but those described are the ones chiefly used. It is, of course, obvious that yarns should be dyed before they are woven into textiles.

Finishing Treatments of Textiles: After weaving textiles on hand looms, some treatment may be necessary to finish them, and there is some difference of treatment for various kinds of yarns. Soft water is best for treatment of the finished fabrics, and in the case of wool, if the water is hard, ammonia should be added.

Before woven textiles are washed they should be carefully examined in a good light for faults, and, if possible, any found should be rectified before the material is inished.

To wash tweed, which is woven wool yarns, place the tweed into warm soapy water, which should not be too hot. Leave the tweed to soak for about twelve hours, then repeat the process, following by rinsing in clear water. All the grease is removed when the tweed squeaks in the fingers. After washing, rinse the tweed thoroughly in warm water and wring it by twisting.

After wringing the tweed before it is nearly dry, roll it round a smooth stick, which should afterwards be withdrawn from the roll. Leave the lengths of tweed rolled for several hours and then press lightly with a warm iron. This treatment is for yarns which have been oiled to make the process of weaving easier.

Unoiled wool should be washed in warm water, adding a little soap only, and should be wrung out but not twisted too hard, then hung until nearly dry before rolling over a smooth piece of wood, later ironing with a moderate iron.

To finish linen, place it in a bath of hot water and add soap if the linen is dirty. After soaking, put the linen through the mangle, then hang to dry before rolling it. After the linen has been rolled for several hours it should be ironed on the wrong side of the material with a hot iron.

Woven silk should be soaked in warm water only, then squeezed to remove as much water as possible, and after hanging until nearly dry, it should be ironed on the wrong side of the material with a moderately heated iron.

To finish cotton, soak it in clear warm water and only add soap if the cotton is dirty. After soaking squeeze out as much water as possible, hang the cotton to dry and when nearly dry, iron it on the wrong side with a fairly hot iron.

Rayon should be finished in clear warm water and soap should not be added unless the work is dirty. When wringing out rayon handle it very carefully, hang the material until it is nearly dry and iron with a warm iron. A hot iron should not be used on rayon.

With finishing, as in any other part of hand-loom weaving, care should be taken at all stages of the work. It should be remembered that although the basic principle is such a simple one, there is much more to hand-weaving than merely darning yarns.

SUN DRYING YOUR FRUITS AND VEGETABLES

For Greater Health for Your Family

Drying the surplus food in the season of plenty can mean more good health foods for the family in seasons when these foods are not available fresh. It can add variety to the diet and make cooking easier because there are more foods from which to plan meals. Drying is not difficult and it requires very little equipment. For the equipment you can use things you already have or can make the necessary pieces easily at home. Drying need cost nothing.

Just What is Drying?

Drying foods does two things. (1) It removes the water and (2) it checks the chemical change that takes place naturally in food, as for example, fruit when it ripens.

WHAT FOODS CAN YOU DRY?

Many different foods are being dried today in various parts of the world. Some foods, which in one country may seem unsuitable for drying, are being dried in others. The tomato is an example of this. In the United States it has been less commonly dried than some other vegetables. In some Middle East countries it has been dried frequently. Here are some of the foods most commonly dried. They have been divided into two groups; those which are easier and those harder to dry.

FRUITS

EASIER	HARDER
APPLES	AVOCADO
APRICOTS	BLACKBERRIES
CHERRIES	BANANA
COCOANUT	BREAD FRUIT

DATES
FIGS
GUAVA
NECTARINES
PEACHES
PEARS
PLUMS
PRUNES

DEWBERRIES
LOGANBERRIES
MAMEY
GRAPES

VEGETABLES

BEANS - Mature-
(Kidney, Lima, Mongo, Pinta, Pole, Red, Black, Soy)
BEANS - dried in green state -
(Lentils, Soy)
CHILI (Peppers)
HERBS (Parsley, Celery tops, etc.)
PEAS - mature -
(Sugar pea, Cow pea, Chuck pea, Pigeon pea)
SWEET CORN
SWEET POTATOES
CASSAVA ROOT
ONION
SOUP MIXTURE

ASPARAGUS
BEETS
BROCCOLI
CARROTS
CELERY
GREENS - (Kintsay, Talinum, Kangkong, Collards, Mustards, Turnip Tops, Beet Tops, Sweet Potato Leaves)
GREEN SNAP BEANS
GREEN PEAS
OKRA
PEPPERS
PIMENTOS
PUMPKIN
SQUASH
TOMATOES

CLEANLINESS EVERY STEP OF THE WAY

Cleanliness is of the greatest importance. It is necessary to follow clean practices every step of the way. What causes food to become dirty? Dust and dirt which fall on the food may contain harmful bacteria. Flies or other insects also carry bacteria on their feet. Some of these bacteria may cause it to spoil more easily. Here are some rules for keeping the food clean as you pick it, prepare it, dry it and store it.

1. Pick or collect food into clean containers.
2. Wash hands before handling food.
3. Wash food carefully in clean water.
4. Cover food drying on trays with clean cloths to keep dust, dirt, flies, and other insects out of it.
5. Wash these covering cloths frequently in clean water.
6. Place trays of food while drying away from dust, insects, and flies.
7. Never lay drying food directly on sand, or ground.
8. Store in tight containers from which dirt and insects can be excluded.
9. Scrub trays or mats after using.

CHECK THE AIR

If you are thinking of drying be sure you have conditions which will bring you success. You need to have these three for the best results.

1. **DRYNESS OF AIR**--Unless the air is reasonably dry the moisture cannot be removed from the food. If it rains all the time it will be hard to dry food.
2. **WARM OR HOT AIR**--Hot days when the sun is shining brightly are best for drying food. Then the food can be dried quickly, which is desirable.
3. **CIRCULATION OF AIR**--There needs to be free circulation of air around the drying food. Make sure that air can reach the foods from all sides, around and underneath, as well as the top of the food.

HOW TO DRY FRUITS

EQUIPMENT NEEDED

Equipment can be very simple for drying fruit. In order to work rapidly after the fruit is picked it will help to get the equipment ready ahead of time. Be sure it is clean. You will need:

1. Sharp knife--to pare and cut fruits (A stainless steel knife prevents discoloration)
2. Wooden board--to make cutting easier
3. Pan, kettle or pot--in which to wash fruit
4. Equipment for sulphuring:

    Large box to cover trays
    Small container for sulphur
    Sulphur
    Small piece of paper
    Matches

5. Plenty of clean water.
6. Trays or mats on which to spread fruit to dry. Trays should be thoroughly scrubbed and dried. See page 431 for suggestions regarding materials to use in making trays and for directions.
7. Pieces of clean, loosely woven cloth--One for each tray or mat. Each piece should be 2 inches (5 centimeters) longer and 2 inches (5 centimeters) wider than tray.

STEPS IN DRYING FRUITS

STEPS HOW-WHY-WHEN

1. Gather fruit
    a. Select Good Quality Food

    The finished food can be no better than the fruit with which you start. Select fresh, ripe, firm and sound fruit. Gather it as early in the morning as possible. When fruit is right for eating it is right for drying.

    b. Handle Carefully

    Fruits bruise easily. Handle with care.

2. Wash fruit

Place fruit in pan. Pour clean water over fruit. Wash carefully. Lift fruit from water. Empty water from pan and repeat if necessary.

STEPS IN DRYING FRUITS - Continued

STEPS HOW-WHY-WHEN

3. Peel or pit fruit--As needed

4. Cut fruit--As needed. Slice into thin pieces. Thick slices dry slowly.

5. Sulphur fruit--Most fruit is improved by sulphuring. Read chart page 436 to see which fruits should be sulphured. See directions page 423 for how to sulphur.

   Why Sulphur? Fruit has better color and flavor. Fruit requires less soaking before cooking. Sulphuring helps to: retain vitamins--prevent souring--prevent insect attacks.

6. Spread fruit on clean dry trays or mats--Spread evenly. One layer in thickness.

7. Cover with loosely woven clean cloth, mosquito netting, or wire screen. To keep insects and dust from getting on the food. Fasten cloth so it will not blow off.

8. Place trays of fruit in sun to dry.

   a. In direct sunlight. This may mean placing the tray flat or it may require raising one edge of the tray.
   b. Where air can circulate freely over and under food. This may require putting tray on blocks or stones.
   c. Away from dust and dirt.
   d. Off the ground.
   e. Away from animals and people.
   f. Protect from storms and dew.
   g. Take in when danger of rain.

9. Turn food. Two or three times each day to speed drying.

10. Continue drying. For several days until 2/3 dry.

11. Test for dryness. Squeeze a handful. If there is no moisture left on the hand and the fruit springs apart when hand is opened, the fruit is properly dried. Berries should rattle on trays.

12. Condition fruit. Gives fruit opportunity to complete drying process and prevents growth of mold.

Take fruit from trays and put in large container. Cover container with cloth or wire screen to prevent insects and dirt from getting into it. Stir fruit 2 or 3 times daily. Leave 8 to 10 days.

13. Put dried food in containers for storage.

Containers in which food is stored need to:
  a. Be moisture proof.
  b. Keep insects out.
  c. Keep dirt from food.

Some good containers are:

  a. Stone jars.
  b. Jars or pots made of clay or metal.
  c. Dry gourds.
  d. Paper bags.
  e. Cloth bags.
  f. Glass jars.
  g. Tin boxes with tight fitting tops.

Small containers are better than large because the food is less likely to become contaminated by mold or insects.

14. Seal containers of food. For containers with loosely fitting lids: Place lid on container, dip strip of cloth (about 1" wide) (2½ centimeters) in melted paraffin or beeswax. Wrap, while warm, around container at joining of lid. Be sure all space between container and lid is covered by strip of cloth.

15. If the food has been put in bags, place the small bags in a large container. Large container may be a jar, crock or pot. Seal large container when filled with small packages.

16. Store. In a clean, dry, dark and cool place. It is well to check food often to see that it remains dry.

HOW TO SULPHUR FRUIT

MATERIALS AND EQUIPMENT NEEDED

1. Trays or rack on which the fruit is spread for drying must not be made of metal.

2. Platform - stones, bricks or blocks of wood to build a platform 6 - 8 inches (15-20 centimeters) high on which the trays can be stacked.

3. Sulphuring Box - wood or cardboard box to cover trays for sulphuring, needs to be deep enough to cover the stacked trays, plus the platform. It must be wide enough to cover not only the trays but also a small pan of sulphur which will be placed at the side of the stack of trays.

4. Pan, tin can or pottery bowl in which to burn sulphur. It should be shallow and clean.

5. Paper - square piece in which sulphur is wrapped. Minimum size - large enough to wrap around a walnut.

6. Sulphur - Allow one level teaspoon of sulphur to each pound (45 grams) of prepared fruit. Don't use too much sulphur.

7. Matches

8. Tray dividers - pieces of wood, or bamboo, which are as long as the width of trays and 1½ inches (about 4 centimeters) wide. Allow two pieces for each tray - stones may be substituted for the pieces of wood. Allow four stones per tray.

GETTING READY

1. Cut opening about 1 inch by 6 inches (3 by 15 centimeters) at bottom of box for ventilation.

2. Build platform of bricks, blocks or stones on which trays can be stacked.

3. Place sulphur on small piece of paper, roll loosely and twist ends so that end of paper may be lighted.

SULPHUR FRUIT OUT OF DOORS

STEPS IN DOING THE JOB

1. Place fruit on trays. The fruit should be only one layer deep.

2. Stack the trays one on top of the other with a space of 1½ inches (about 4 centimeters) between them. Use strips of wood, piece of bamboo or stones to separate the trays. Fumes of sulphur must be able to circulate freely around the fruit.

3. Place twist of paper containing sulphur in small metal or crockery container.

4. Set the sulphur container by side of the stack of trays and set fire to the twist of paper containing sulphur.

5. Quickly cover stack of trays and sulphur dish with box. It should cover trays completely. Close opening in box as soon as sulphur is burned to prevent loss of fumes.

6. For length of time fruit should be sulphured see chart page 436.

7. Remove cover and place trays to dry.

HOW TO DRY VEGETABLES

EQUIPMENT NEEDED.

Collect equipment before gathering vegetables.

1. Knife (for most vegetables).
2. Wooden board for cutting.
3. Pans or pots in which to wash vegetables.
4. Plenty of clean water for thorough washing.
5. Pot or kettle in which to steam vegetables.
6. Lid which fits the pot or kettle in which vegetables are steamed.
7. Equipment for steaming. A rack and basket or a cloth bag and stick.
8. Rack, trays or mats on which the vegetables can be spread to dry.
9. One piece of loosely woven, clean cloth for each tray or mat above. These should be slightly larger than the tray or mat on which they are to be used.

STEPS IN DRYING VEGETABLES

STEPS	HOW - Why - When
1. Gather vegetables.	Select good quality, firm sound vegetables. Avoid overripe vegetables. Harvest early in the morning or late in the day. Avoid delay between harvesting and processing.

2. Wash vegetables.	Use plenty of clean water. Place vegetables in pan. Pour clean water over vegetables. Wash thoroughly. Scrub if necessary. Lift from water. Empty water from pan. Repeat if necessary.
3. Prepare vegetables.	Follow directions on page 436 for each vegetable. This may be: Shelling Hulling Peeling Slicing Work rapidly.
4. Steam most vegetables. (See page 436 for length of time to steam.)	Steaming helps to: a. Retain vitamins. b. Retain minerals. c. Give better color and flavor. d. Reduces time needed for soaking before cooking. See page 428 for directions on how to steam.
5. Spread vegetables on clean dry trays or mats.	One layer in thickness Spread evenly.
6. Cover with loosely woven clean cloth, mosquito netting or wire screen.	To keep insects and dust off food. Fasten cloth down so it will not blow off.

STEPS IN DRYING VEGETABLES - Continued

STEPS	HOW - WHY - WHEN
7. Place trays in sun to dry.	a. In direct sunlight. b. Where air can circulate freely. c. Away from dust and dirt. d. Off ground. e. Away from animals and people. f. Protect from storms and dew. (See page 433 for suggested places to dry.)
8. Turn food.	Two or three times each day to speed drying.
9. Continue drying.	For several days until 2/3 dry.
10. Test for dryness.	Squeeze handful.
11. Condition vegetables.	In large containers for 8 to 10 days.
12. Put in containers for storage.	Several small containers are better than large ones.
13. Seal containers.	To exclude air. To keep out insects.
14. If food is in bags, place the small bags in a large container.	Seal large container.
15. Store.	In clean, dry, dark, cool place.

HOW TO STEAM VEGETABLES

To steam vegetables they must be suspended in live steam above rapidly boiling water in such a way that the steam reaches all the pieces of the vegetables quickly without the vegetables resting in the water. This means the vegetables must be held loosely and not be allowed to pack. Small amounts of the vegetable pieces need to be steamed at one time to insure the steam reaching all the vegetables and to avoid overcooking some while others remain raw.

Two methods of steaming have been used successfully in different countries. Each method with equipment used is described in the following:

METHOD I.

EQUIPMENT NEEDED.

1. A deep container with tight fitting cover. A pot or kettle used for preparing soups, main dish or stew for the family would be fine for this. If it does not have a cover which fits tightly, something should be improvised to serve as a cover and hold the steam inside the kettle. A board could be laid over the opening. The board needs to be large enough to cover the opening completely and hold in the steam. Placing a weight on top will help with this.

2. Rack which can be put in the bottom of this container and used to hold the vegetables up out of the boiling water. It will need to be 1½ to 2 inches (3½ - 5 centimeters) high and be so constructed that it permits the water to boil freely around or through it. A wooden rack made of slats is often used for this. An equally satisfactory rack can be made of bamboo, or woven of reeds.

3. Container to hold vegetables while being steamed. This must:
   (a) Fit inside the steaming pot;
   (b) Hold the vegetables loosely,
   (c) Be open enough in construction that the steam can reach all parts of the vegetables.

This container can be a colander, wire basket, or reed basket. Improvised baskets can be made of wire fencing; wire screening; weaving materials such as grasses, reeds, or vines. If none of these are available, a second pot could be set on the rack inside the larger pot.

STEPS IN STEAMING VEGETABLES

STEPS	HOW - WHY - WHEN
1. Put rack in bottom of deep container.	As a support for the steaming basket.
2. Put 1 inch (2¼ centimeters) of water in deep container and bring to boil.	Put lid on container to hasten boiling.
3. Put layer of prepared vegetables in basket.	Make layer of vegetables thin - not more than 2¼ inches (7 centimeters) deep.
4. Place basket on rack in bottom of deep container.	Vegetables should not touch water.
5. Place lid on container.	Lid needs to fit tightly to keep steam in container. Place weight on lid if necessary.
6. Count time as soon as kettle fills with steam.	Minimum time indicated on chart has been found best, except when vegetables are older, have been gathered longer, or were grown under very dry conditions. These vegetables may need longer steaming.
7. Test to see if vegetables are completely steamed.	Each piece of vegetable must be heated through and wilted. Remove a piece from center of steamer and press it. It should feel tender but not completely cooked.

METHOD II

EQUIPMENT NEEDED.

1. Deep container with tight fitting lid.
2. Piece of loosely woven, clean cloth in which vegetables can be tied loosely and hung in the container. The size of this will depend on the size of the steaming kettle used. It is important not to crowd the vegetables or the steam will be unable to reach all of them.
3. A piece of wood, stick or bamboo which can be wedged across the kettle near its opening, to which the bag of vegetables can be hung.

STEPS IN STEAMING VEGETABLES

STEPS	HOW - WHY - WHEN
1. Place piece of wood, stick or bamboo in top of deep container	Just far enough below rim edge of container to permit lid to be placed tightly on container.
2. Put 1 inch (2½ centimeters) of water in container and bring to boil.	Put lid on container to hasten boiling.
3. Place vegetables in piece of loosely woven clean cloth.	Vegetables must be very loose in bag.
4. Tie cloth to form a bag.	Bring opposite corners of cloth together and tie. Repeat with remaining two corners. This knot should be tied far enough from the corners to: (a) Leave ends long enough to tie over stick in top of container. (b) Keep the bottom of the bag from touching the water when the bag is tied on the stick.

5. Tie bag to stick securely.	So that bag of vegetables does not touch water.
6. Place lid on container.	Lid needs to fit tightly to keep steam in container.
7. Count time as soon as container fills with steam.	Minimum time on chart has been found best, except when vegetables are older, have been gathered longer, or were grown under very dry conditions. These vegetables may need longer steaming.
8. Test to see if vegetables are completely steamed.	Remove a piece from center of vegetables and press it. It should be heated through and wilted. It should feel tender but not completely cooked.

DRYING TRAYS

SIZE -

Here are some guides and suggestions to help you select or make your own trays.

1. Since you will need to move the trays after they are loaded they should be no larger than you can handle easily.
2. Under most circumstances a few larger trays will be easier to care for and spread food on than many small trays.
3. Where are you going to place trays so that the sun can reach the food? How large is this space? Will a few large trays rest better here or several smaller trays?
4. What do you already have on hand which can be used for drying trays? It may be better to improvise with something you have in the home now than go to the expense or spend the time to make new ones.

5. Trays of uniform size are easier to stack when you must bring them in at night or out of the rain. It also may make it easier to store them in seasons when you are not using them.

6. A size of trays which has been found to be convenient is 14 by 24 inches. (35 X 60 centimeters)

SHAPE -

Any shape - round, square, rectangular - is satisfactory. Trays of uniform shape can be easily and quickly stacked.

BOTTOM OF TRAY -

The bottom of the tray needs to have openings to allow passage of air. Air needs to reach all sides of the food for rapid drying. For trays made of wood, allow spaces between slats. If trays are made of reeds or grasses, use an open work weaving pattern. Do not make the bottom of the tray solid.

SIDES ON TRAYS -

Trays with sides on them are better than those without sides because they -

1. Keep foods from sliding off when you move the trays.
2. Make stacking easier.
3. Keep trays from resting on food when you stack them.
4. Provide an edge to which cloth may be fastened.

MATERIALS FOR TRAYS

Trays can be made of many materials. Here are a few:

a. Scrap lumber or wooden boxes are sources of wood to use in building trays.

b. Bamboo, or similar wood.

c. Small limbs of tree for frame and vines like honeysuckle woven in between to form drying surface.

d. Frame of wood with thongs of leather woven in to form the rack.

e. Screen wire attached to bottom of wooden frame.

f. Grass or straw matting woven or cut in suitable sizes.

SOME GOOD PLACES TO DRY FRUITS AND VEGETABLES

1. On the roof of the house.
2. On an improvised table by the house.
3. On an elevated platform built a few feet above the ground level. Below are suggestions
    (a) Wooden or bamboo rack.
    (b) Mound of adobe bricks or stones.

SOME SPECIAL FRUITS AND VEGETABLES

Cocoanut

Remove meat from shell.
Cut meat in thin slices.
Place on trays.
Cover trays with clean loosely woven cloth and place in sun until well dried.
Store in tight cans or jars.

May be added to puddings, candies, eaten as a sweet or used in place of nuts. When sprinkled with salt may be used as appetizer.

Peanuts

Peanuts are high in food value and may be served as a part of a meal. They should be gathered when mature and spread on trays to dry in the sun. Peanut butter, which can be used as the basis for a number of tasty dishes is made as follows:

Peanut Butter Recipe

2-3/4 cups peanut
(400 grams)

1/2 teaspoon salt
2 tablespoons sugar

Roast peanuts, remove skin. Pass peanuts through a stone or meat grinder as many times as needed to make it fine and smooth. Add salt and sugar. Pass again through grinder several times until a very smooth paste is obtained. Pack in sterilized jars and seal tight.

Cassava

Shred fresh cassava rootstocks into small chips. Dry the shredded chips and cut into small pieces, preferably like rice grains. The cassava chips can then be used to extend the rice or be prepared in a variety of nutritious and delicious dishes. To extend rice, use 1 part cassava chips to 4 parts of rice. Mix with washed rice and cook.

Soup Mixtures - Choose available vegetables that will give a pleasing combination. Dry them separately according to instructions for that vegetable, then combine and store in one container for a soup mixture, chowder, or stew.

Herbs and Seasonings - Parsley leaves, mint, celery leaves, sage, dill, and other herbs, are not blanched before the drying process begins. Choose plants that are well developed, wash and hang up in an airy, breezy, shady place. They are brittle and bone dry when done. The herbs may be broken up when dry to save storage space.

HOW TO PREPARE DRIED FOOD FOR USE

RESTORING (Soaking)

Most fruits and vegetables should be covered with cold water and soaked to restore the moisture removed by drying. Usually soaking 1/2 hour to 2 hours will give an acceptable product, although longer soaking, 2 to 6 hours, may result in increased tenderness.

The food should be kept covered while soaking. The amount of water used for soaking should be as near to that which the food can take up as possible. It is better to add water during the soaking process than to start out with more than is needed.

COOKING

Cook the food in the same water in which it has been soaked because there are some minerals dissolved in the water.

Boil vegetables until tender. Add water for cooking if all the water used in soaking has been absorbed.

Cook greens, cabbage, tomatoes, soup mixtures and powdered vegetables without soaking. Drop them into enough water to cover and cook until tender.

Dried tomatoes, okra, pepper, string beans and corn added to a meat stew or soup make an excellent dish when fresh vegetables are not available in the family garden.

FLAVORING

Vegetables on drying lose much of their fresh flavor. Therefore, the addition of such flavoring as basil, garlic, onion or other herbs will be desirable.

FRUITS

Usually 1/4 cup of sugar per cup of dried fruit is sufficient for dried apples, pears, or peaches. Less sugar is needed for dried than for fresh fruit because in the drying process the starch in the fruit is changed to sugar. When sugar is used it should be added at the end of the cooking period so as not to interfere with the absorption of water by the fruit. Adding a few grains of salt helps to bring out the natural sweetness of the fruit. Lemon, orange, or grapefruit juice added to the dried fruit just before serving will give a fresh fruit flavor and add vitamin C to the dish.

CONDENSED DIRECTIONS FOR PREPARING AND SUN DRYING SOME FRUITS AND VEGETABLES

ITEM	Selection and Preparation	Treatment before Drying		Tests for Dryness
		Method	Time in minutes	
FRUITS:				
Apples	Peel and core. Cut into slices or rings about 1/8 inch thick.	Sulfur	60	leathery; glove-like; section cut in half, no moist area in center
Pears	Peel, cut in half lengthwise, and core Section or cut into slices about 1/8 inch thick	Sulfur	(60, sliced) (120 quartered)	Springy feel
Large stone fruits	Peel and slice peaches. Cut in half and pit apricots, nectarines, and large plums and prunes. Fruits dry more rapidly if cut in quarters or sliced.	Sulfur	(60, sliced) (120, quartered)	pliable; leathery; a handful of prunes properly dried will fall apart after squeezing.
Berries (except strawberries)	Pick over; remove defective, wash.	Steam	½ to 1	hard; no visible moisture when crushed.
Cherries	Pick over, remove defective, wash, pit.	No further treatment		leathery but sticky
Figs	If figs are small or have partly dried on the tree, they may be dried whole without blanching. Otherwise, cut in half	Steam	20	leathery; flesh pliable; slightly sticky.
Grapes	Only seedless varieties should be dried Pick over, remove defective.	No further treatment		Pliable; leathery
VEGETABLES:				
Asparagus	Cut tender green tips only	Steam	4 - 5	Brittle, greenish black
Beans-green snap	Remove defective pods. Wash and remove strings from string varieties. Split pods lengthwise, to hasten drying.	Steam	15 - 20	Brittle
Beets	Select small, tender beets of good color and flavor, free from woodiness. wash; trim the tops but leave the crowns; steam for 30-45 mins. until cooked through. Cool; trim off the roots and crowns; peel, Cut slices about 1/8" thick.	No further treatment		tough; leathery

Brocooli	Trim and cut as for serving. Wash. Quarter stalks lengthwise	Steam	8 - 10	Brittle
Cabbage	Remove outer leaves, quarter, and core Cut into shreads about 1/8" thick	Steam	5 - 6 wilt	tough to brittle
Green chili or Peppers	Use full grown pod, bright green Peel and slit pod; remove seeds and dry	No treatment		Crisp, brittle medium green
Red chili or peppers	Use mature pod, dark red. String and hang in sun.	No treatment		Shrunken pod, flexible, dark red
Carrots, turnips rutabagas	Select crisp, tender, free from woodiness. Wash. Trim off roots and tops. Peel thin. Cut into slices or strips about 1/8" thick	Steam	8 - 10	tough; leathery
Corn, cut	Select tender sweet corn. Husk. Steam 10-15 min., or until milk is set. Cut from cob	No further treatment		dry; brittle
Leaves for seasoning; celery; parsley	Wash	No treatment		brittle
Onions, garlic	Remove outer discolored layers. Slice	No treatment		brittle; light colored
Peas	Select young, tender peas of a sweet variety. Shell	steam immediately	10	hard; wrinkled; shatter when hit with a hammer
Potatoes	Peel, cut into shoestring strips 3/16" in cross section, or cut into slices about 1/8" thick.	Rinse in cold water steam	4 - 6	Brittle
Spinach and other greens	Select young, tender leaves. Wash. See that leaves are not wadded when placed on trays. Cut large leaves crosswise into several pieces to facilitate drying	Steam	4, or until thoroughly wilted	Brittle
Squash	Wash, peel, and slice in strips 1/4" thick.	Steam	6	tough to brittle
Squash (Hubbard) Pumpkin, yellow	Cut into strips about 1" wide. Peel off the rind. Scrape off the fiber and seeds. Cut peeled strips crosswise into pieces about 1/8" thick.	Steam	Until tender	tough to brittle
Sweet potatoes	Wash, peel, trim and cut into 1/4" slices (alternate method-steam before peeling).	Steam	Until tender	tough to brittle
Tomatoes for stewing	Select tomatoes of good color. Steam or dip in boiling water to loosen skins. Chill in cold water. Peel. Cut into sections, not over 3/4" wide. Cut small pear or plum tomatoes in half.	No further treatment or may sulfur	10 - 20	leathery

ABSTRACT - HAND GRINDER

This hand-powered grinder will grind corn, wheat or other grain coarse or fine. It is simple in design and easily built by a carpenter, being made almost entirely of plain one inch lumber.

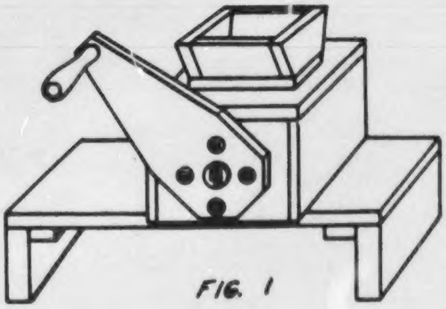


FIG. 1

TOOLS AND MATERIALS

Tools -
Hammer
Hand cross cut saw
Auger brace and 1/4, 1/2 and 7/8 inch auger bits.
Round file
Coping saw or key hole saw
Breast drill and 1/8" twist drill
One flat file
One three corner file
1/2" x 13" die and die handle
5/16" die
Wood chisel
Half round wood file
Tin shears
Screw driver

Materials -
12 feet of 1" x 6" seasoned sheathing lumber
2 feet 1" x 10" sheathing lumber
2 feet 2" x 8" framing lumber
3 feet 2" x 4" framing lumber
1 piece 1/2" x 14" cold rolled steel
12 - 1 1/2" x 8" flat head wood screws
3 - 1/2" steel washers
4 - 1" x 4" carriage bolts
1 - 1/2" wing nut
1 - 3/8" x 5" carriage bolt
2 cast iron burrs. (The cast iron burrs are available from Booher Equipment Company, 3627 Devon Drive S. E., Warren, Ohio, for about $.50 plus postage.

DETAILS

Through the following discussion 1" lumber refers to the standard board thickness for surfaced sheathing lumber in the United States. It actually measures only about three quarters of an inch in thickness. All dimensions are in inches. Lumber used should be flat and well seasoned. The numbers in the next section refer to part numbers shown in Figure 2 and subsequent detailed part sketches.

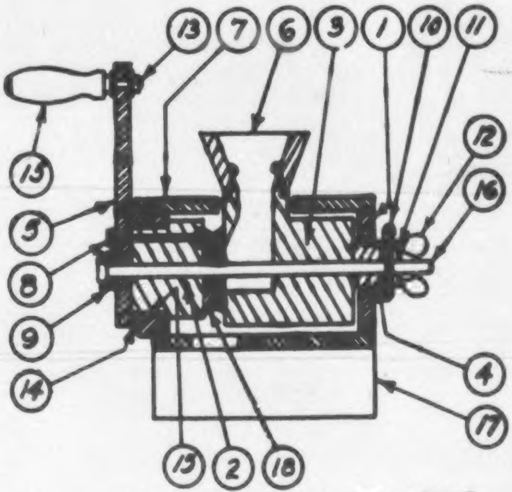
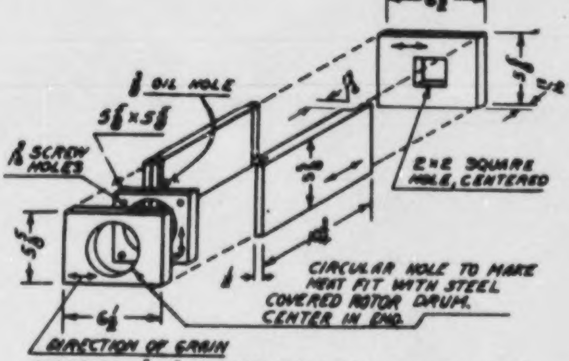


FIG. 2. ASSEMBLY DWG.

1. Grinder Body - make of 1" x 6" pine or hard wood lumber. Circular hole can be cut with coping saw or jig saw but for a better and quicker way to cut see Notes 1 and 2, Figures 3 and 4.

2. Rotor - See Note 2. Take care to bore the 1/2" holes thru each part where required accurately and at right angles to the surface of the part. If

when placed on the assembly post, it does not lie flat to the assembly post surface marked "A" in Figure 3 or against an adjacent part because the hole is not bored straight, remove it from the assembly post and use a round file in the hole carefully until it will lie flat. Use a few spots of glue between parts. Be careful in nailing so nails will not interfere with boring the 1/4" holes later. Keep the nails within 1" of the center post. 1 1/2" finishing nails are about right.


OIL HOLE
SCREW HOLES
2x2 SQUARE HOLE, CENTERED
CIRCULAR HOLE TO MAKE NEAT FIT WITH STEEL COVERED ROTOR DRUM. CENTER IN END.
DIRECTION OF GRAIN

MAKE OF 1"x6" LUMBER. THE TWO PARTS OF FRONT END ARE FASTENED TOGETHER WITH SCREWS AND GLUE. SEE NOTE NO. 2 FOR CUTTING CIRCULAR HOLE. ASSEMBLE SIDES TO ENDS WITH SCREWS OR NAILS

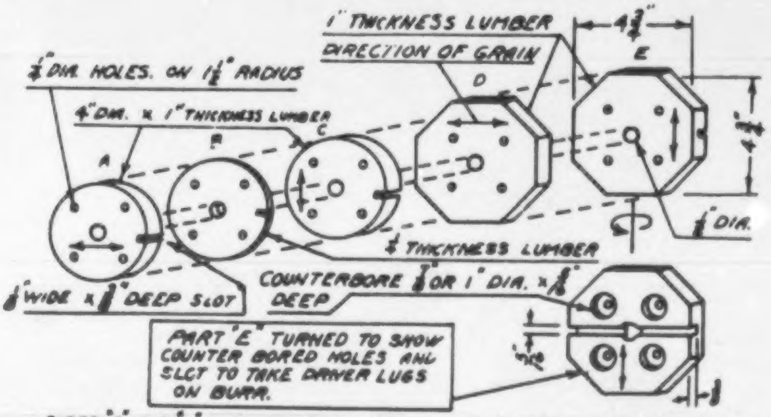
① GRINDER BODY. EXPLODED VIEW

It is a help in getting the metal band snugly on the rotor drum to form the 3/8" lip on one end first, then bend the band around some round object that is about 3" in diameter. Next put it on the rotor drum with the one lip engaged in the slot. Use strong twine or flexible wire to pull band snugly around drum and mark position of the second lip. Remove from rotor, form the second lip and cut off excess. The band may need to be formed a little with the fingers. It should now fit snugly.

3. Stationary Burr Holder - In boring 1/2" holes and assembling follow the instructions given under (2). Assemble the parts using a few spots of glue and nails. 1 1/2" finishing nails are about right.

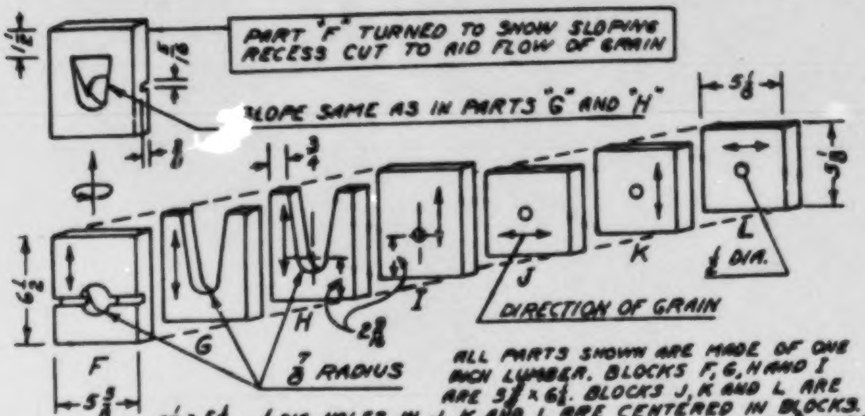
4. Follow instructions under (2) Rotor for assembling parts of the thrust block.

5. The 1/4" holes can best be located by placing the rotor and crank al on the assembly post. With bolts in place thru rotor, mark location for holes on crank by tapping with a hammer. Oil hole in the crank is bored to reach the 1/2" hole. This will supply oil to the steel shaft.


1" THICKNESS LUMBER
DIRECTION OF GRAIN
DIA. HOLES. ON 1½" RADIUS
4" DIA. x 1" THICKNESS LUMBER
A
B
C
D
E
DIA.
THICKNESS LUMBER
COUNTERBORE OR 1" DIA. x DEEP
WIDE x DEEP SLOT
PART "E" TURNED TO SHOW COUNTER BORED HOLES AND SLOT TO TAKE DRIVER LUGS ON BURR.

DISCS "A" AND "C" ARE CUT FROM FRONT END BOARDS OF GRINDER BODY USING CIRCLE CUTTER. SEE FIG. 4. CUT DISC "B" FROM ¾" PLYWOOD OR PLAIN ¾" THICK LUMBER. BORE ½" DIA. HOLES IN CENTER OF EACH PIECE, THEN STARTING WITH PART "E", PLACE OVER ASSEMBLING POST WITH SLOT DOWN. ASSEMBLE OTHER PARTS AS SHOWN. USE 1½" NAILS AND GLUE. MAKE COUNTERBORES AND ¼" HOLES AFTER ASSEMBLING. PUT THE FOUR ¼" BOLTS IN HOLES WITH HEADS IN COUNTER-BORES. ATTACH BURR WITH 1½ x 8 WOODSCREWS.

② EXPLODED VIEW OF ROTOR

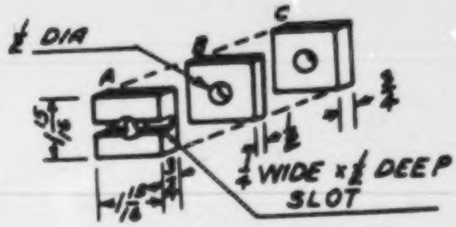

PART "F" TURNED TO SHOW SLOPING RECESS CUT TO AID FLOW OF GRAIN
SLOPE SAME AS IN PARTS "G" AND "H"
5 1/8
3/4
F
G
H
I
J
K
L
1/2 DIA.
DIRECTION OF GRAIN
7/8 RADIUS
2 9/16
5 3/8
6 1/2

ALL PARTS SHOWN ARE MADE OF ONE INCH LUMBER. BLOCKS F, G, H AND I ARE 5 3/8 x 6 1/2. BLOCKS J, K AND L ARE 5 1/8 x 5 1/8. 1/2 DIA. HOLES IN J, K AND L ARE CENTERED IN BLOCKS. TO ASSEMBLE PUT PART "F" ON ASSEMBLY POST WITH 1/2 WIDE SLOT DOWN. CENTER CAREFULLY AND HOLD IN PLACE WITH 2 SMALL NAILS. ASSEMBLE PARTS G, H, I, J, K AND L TO IT USING 1 1/2 FINISH NAILS AND GLUE. ATTACH BURR.

③ EXPLODED VIEW OF STATIONARY BURR HOLDER.

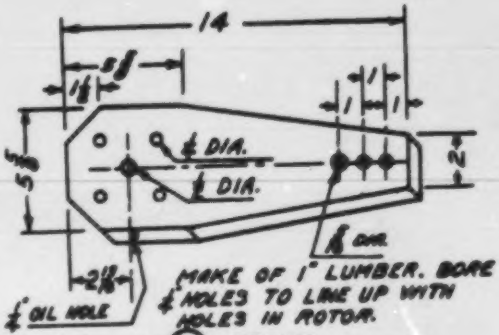
6. Attach hopper to top of stationary burr holder with screws. See Figure 2.

7. Cover


1/2 DIA
A
B
C
3/4
1/2
1 15/16
1/4 WIDE x 1/2 DEEP SLOT

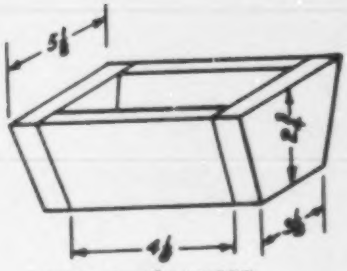
AFTER BORING HOLES AND CUTTING SLOT, ASSEMBLE PARTS A, B AND C USING SMALL NAILS AND GLUE. TOTAL THICKNESS OF A, B AND C IS 2"

④ EXPLODED VIEW OF THRUST BLOCK.


14
5 1/8
1 1/8
1
1
1
5 1/8
2
1/4 DIA.
1/4 DIA.
1/2 DIA.
2 13/16
1/4" OIL HOLE

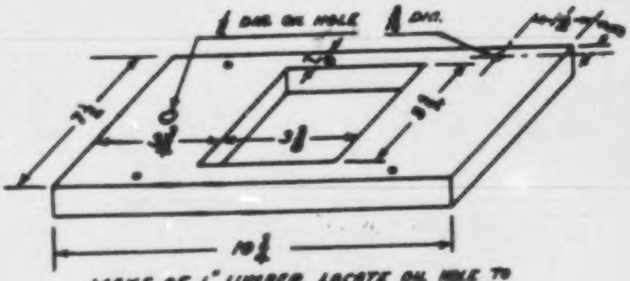
MAKE OF 1" LUMBER. BORE 1/4 HOLES TO LINE UP WITH HOLES IN ROTOR.

⑤ CRANK


5 1/8
2 1/4
4 1/8
3 1/8

MAKE OF 1" LUMBER

⑥ HOPPER


1/4 DIA. OIL HOLE
1/4 DIA.
7 1/2
3 1/2
3 1/8
10 1/4

MAKE OF 1" LUMBER. LOCATE OIL HOLE TO LINE UP WITH OIL HOLE IN GRINDER BODY

⑦ COVER

8. Four 1/4" x 4 1/2" carriage bolts with nuts and 8 washers.

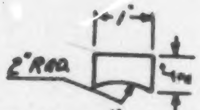
9. Two steel washers for 1/2" diameter bolts.

10. Two 1/8" diameter x 2" cotter key. If a larger diameter cotter key is used, drill the hole to suit. The hole should not in any case be more than 5/32".

11. Three steel washers for 1/2" bolt.

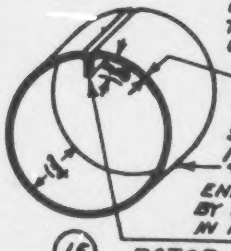
12. One 1/2" winged nut.

13. One 5/16" diameter carriage bolt threaded 1 1/2". File square shank under head to roundness. Length 4 1/2".



MAKE OF 1/8" THICKNESS WOOD OR LEATHER. GLUE TO FRONT OF GRINDER BODY AROUND CIRCULAR OPENING. 4 REQUIRED.

⑭ CLEARANCE BLOCKS



ABOUT 28 GAGE OR THICKNESS OF STEEL USED IN SQUARE 5 GAL. OIL CANS.

REQUIRES A STRIP OF SMOOTH SHEET STEEL 1 3/8 x APPX. 13 1/4.

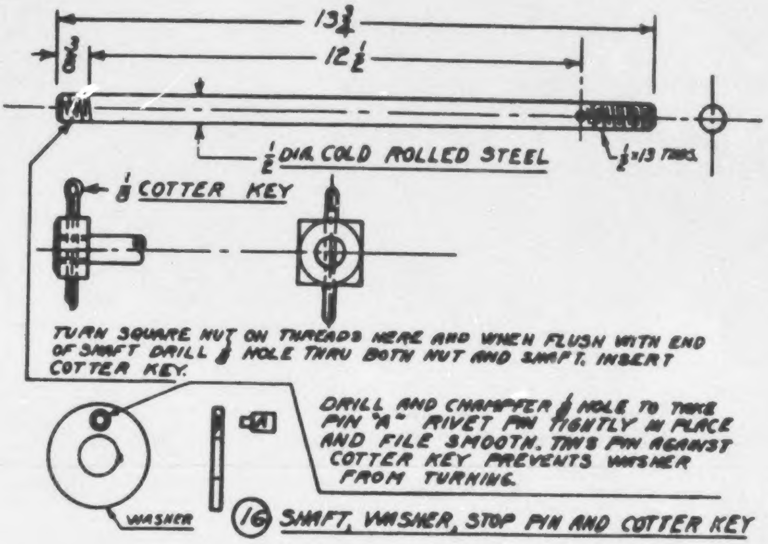
ENDS ARE HELD TOGETHER BY ENGAGING THEM IN SLOT IN ROTOR DRUM.

⑮ ROTOR DRUM BAND

14. Clearance Block - The purpose of the clearance block is to keep the crank from rubbing the front of the grinder. Locate the clearance blocks at even quarters around circular opening in front of grinder body.

15. Rotor Drum Band - In making this part and attaching it to rotor read the discussion under Rotor (2).

16. Steel Shaft - Threading is U.S. standard, 1/2" x 13 threads per inch.



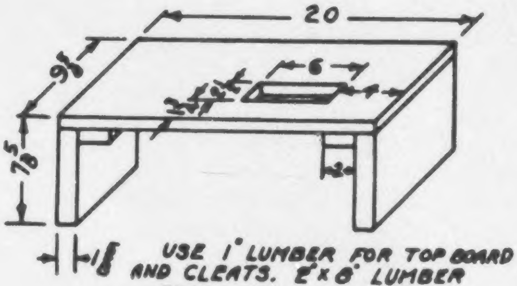
TURN SQUARE NUT ON THREADS HERE AND WHEN FLUSH WITH END OF SHAFT DRILL 1/8 HOLE THRU BOTH NUT AND SHAFT. INSERT COTTER KEY.

DRILL AND CHAMFER 1/8 HOLE TO TAKE PIN "A" RIVET PIN TIGHTLY IN PLACE AND FILE SMOOTH. THIS PIN AGAINST COTTER KEY PREVENTS WASHER FROM TURNING.

⑯ SHAFT, WASHER, STOP PIN AND COTTER KEY

17. Grinder Stand.

18. Two cast iron burrs. See materials.



USE 1" LUMBER FOR TOP BOARD AND CLEATS. 2"x8" LUMBER FOR LEGS.

⑰ GRINDER STAND

FINAL ASSEMBLING

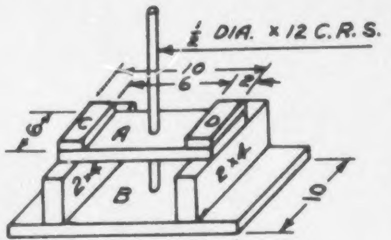
After all parts are completed the next step is to fully assemble the mill. The rotor with burr attached is placed in its position in the circular opening. Attach the crank. Next put the stationary burr holder in position and insert the steel shaft thru both parts. Put the thrust block in place, insert the cotter key, put on steel washer and run up the winged nut. In making the final adjustment it may be necessary to add one or more steel washers between thrust block and burr holder or to shorten the thrust block. When the winged nut is tight, there should be a little play between the cotter key and the bottom of the slot in thrust block.

Before putting on the cover turn the rotor and observe the burrs carefully. They should remain flat to each other when rotor is turned. If there is an opening which travels around as the rotor turns, a shim is needed under the burr on the rotor. Mark the place and note thickness of shim required. If the opening remains stationary a shim is needed under the burr on the burr holder. Remove the necessary part and add a shim. Of course, both burrs may need shims. A little glue under the shims makes a permanent job.

NOTES -

The purpose of the following is to facilitate and speed up the job of making the mills. It is assumed the mills will be made in a carpenter shop as a business. The notes along with Figures 3 and 4 describe two devices that will be found very useful in shops making these mills.

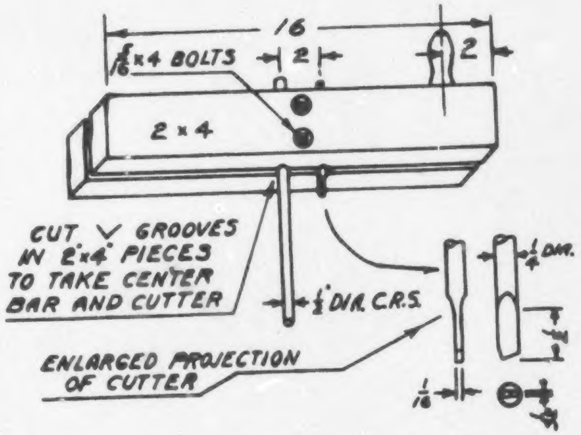
NOTE 1 - See Figure 3. The use of the assembly post is described under (2) and (3). In constructing the assembly post, care should be taken to make it very solid and strong and the steel post must be square with the surface marked "A" in Figure 3. A good way is to build the entire wood part of the device "C" and "D" before boring the holes for the steel post. When ready to bore these holes, bore thru "A" first, then push the bar thru to "B" and testing carefully with a square move top of bar until it tests square both ways then strike the bar on its top end to mark position of the auger hole in "B". Last, put on "C" and "D".



ALL WOOD PARTS ARE 1" LUMBER EXCEPTING THE 2 PARTS MARKED 2×4.

FIG. 3. ASSEMBLY POST

NOTE 2 - See Figure 4. The purpose of this device is to cut the circular discs out of the end boards of the grinder body. Test each on the assembly post to be sure the holes are square thru these members. Use a round file if the member does not lay flat on "A" of the assembly post. Place the pieces one at a time on the rod of the disc cutter. Remove the steel rod from the assembly post and pass the steel rod of the disc cutter thru both holes of the



16
$\frac{5}{16}$×4 BOLTS
2
2
2×4
CUT V GROOVES IN 2"×4" PIECES TO TAKE CENTER BAR AND CUTTER
$\frac{1}{2}$" DIA. C.R.S.
$\frac{1}{4}$ DIA.
ENLARGED PROJECTION OF CUTTER
$\frac{1}{16}$

FIG. 4 DISC CUTTER

assembly device. The assembly device with disc cutter in place should now be held in a bench vise or fastened to a wall so the shaft is horizontal and at a convenient height for turning. Turn the crank and exert a gentle pressure to bring the cutter into play.

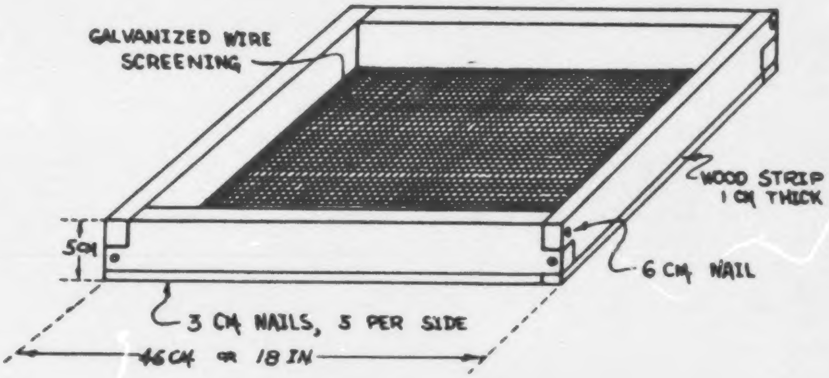
The steel cutter should be of tool steel. A six inch length of drill rod is excellent. If this is not available, a screw driver with approximately a 1/4" diameter shank can be shaped up with a file to do the job. In operating the disc cutter cut only half way thru the member then reverse and complete from other side.

For greater strength the cutter can be made more then 1/16" in thickness. This will make the discs that compose the rotor drum fit too loosely even after the steel band is on but the difficulty is easily corrected by giving the drum several turns of heavy wrapping paper before the steel band is applied. The paper should be glued to the drum.

SEED CLEANING SIEVES

ABSTRACT

The set of sieves described here will clean your crop seeds effectively, which is an important step for improved crop production.



TOOLS AND MATERIALS

12 - boards
    2½ x 5 x 46 cm.
    1" x 2" x 18"
12 - wood strips
    1 x 2½ x 43½ cm.
    ¼" x 1" x 17"
1 - 46 cm (18 in.)
    square of ¼" galvanized screen.
1 - same but 3/16" screen
1 - same but 1/8" screen
Hammer, saw, nails.

DETAILS

The exact size of these sieves is not important, but 1/8", 3/16" and 1/4" mesh make convenient sizes for cleaning wheat, barley, corn and seeds of similar size. The sieves are also useful for grading certain seeds. Grading consists of removing the small, weak seeds which will produce small weak plants or will not grow at all. Less seed can be planted per acre, if it is properly cleaned and graded, and still produce a good crop.

BUCKET SPRAYER

ABSTRACT

This simple sprayer works on the same principle as the inertia pump, and is designed so that local artisans can make it. Two people operate it; one sprays while the other pumps.

TOOLS AND MATERIALS

Galvanized iron 30 cm x 30 cm plus 10 cm x 20 cm
Barrel metal 10 cm x 20 cm
1/4" hose (high pressure) 4 m.
1/4" pipe (truck brake line may be used) 50 cm
Wood for handle 2 cm x 15 cm x 30 cm.
3/4" galvanized iron pipe (thin-wall) 120 cm long
4 mm wire-20 cm
Truck inner tube material 10 cm x 20 cm
1 mm galvanized wire 30 cm
4 - 3/16" bolts 1 cm long
2 - 3/16" bolts 3 1/2 cm long

DETAILS

The bucket sprayer described here has been designed primarily to meet the need for a sprayer which can be built in an area where production facilities are limited. This sprayer can be made by the local artisans. It is intended only for water solutions of insecticides or fungicides.

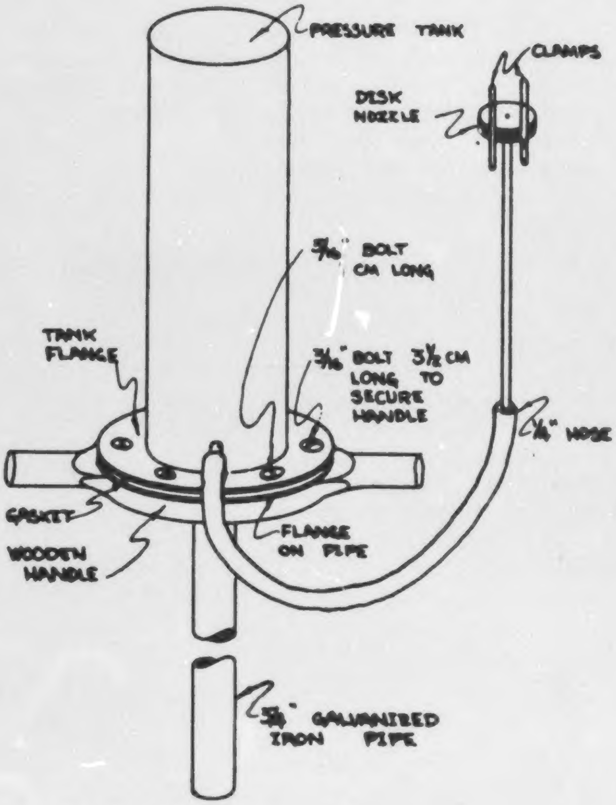

PRESSURE TANK
CLAMPS
DISK NOZZLE
3/16" BOLT CM LONG
TANK FLANGE
3/16" BOLT 3½ CM LONG TO SECURE HANDLE
1/4" HOSE
GASKET
WOODEN HANDLE
FLANGE ON PIPE
3/4" GALVANIZED IRON PIPE

FIG 1

The sprayer pump is of the inertia type which consists of a 3/4" iron pipe with the top plugged and a simple valve located 8 cm. from the top. The valve is a piece of truck inner tube rubber wrapped around the pipe and held in place by wire. One corner of the rubber is over a hole in the pipe. Some careful adjustment is necessary when placing the rubber to make sure it works properly and does not leak.

The pressure tank encloses the valve assembly and, as the liquid is pumped into the tank, builds up pressure sufficient to operate the simple disk type spray nozzle. The tank is built so that it can be removed in order to service the valve.

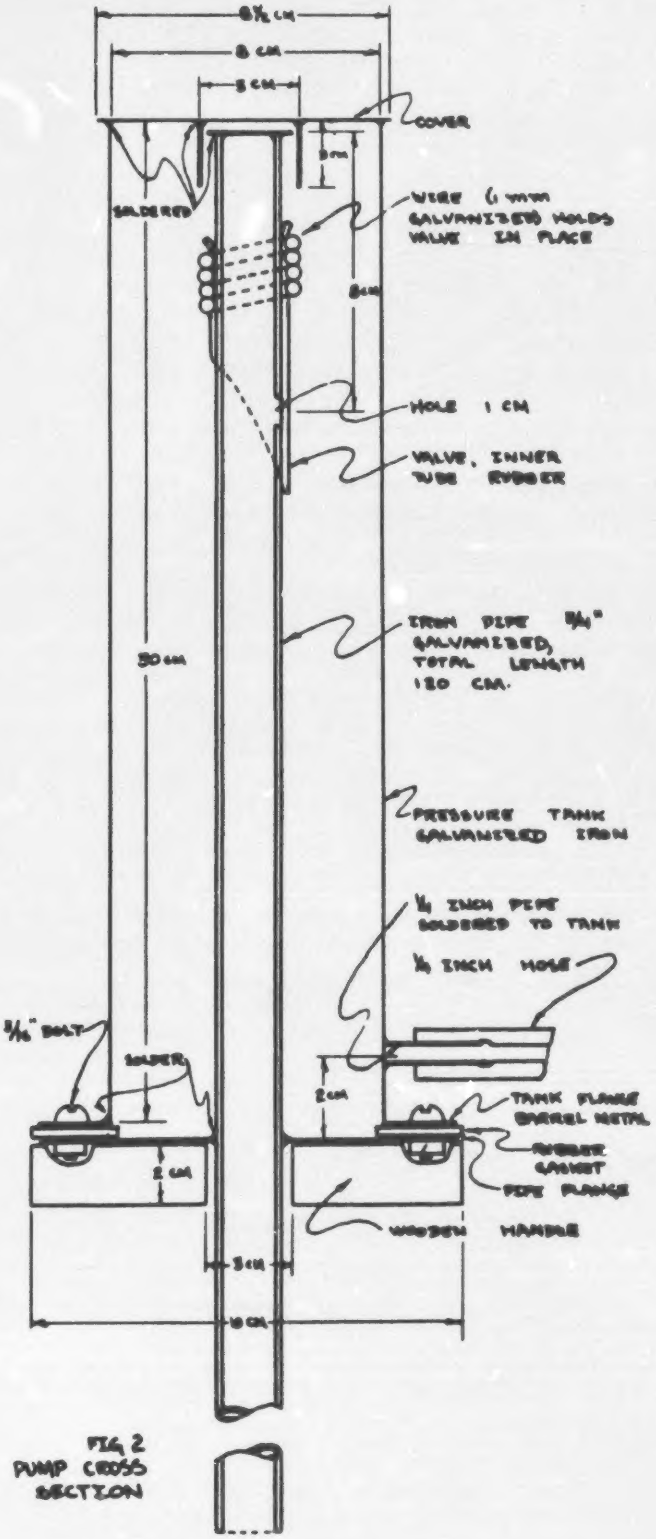

8½ cm
8 cm
3 cm
COVER
2cm
SOLDERED
WIRE (1 mm GALVANIZED) HOLDS VALVE IN PLACE
8cm
HOLE 1 CM
VALVE, INNER TUBE RUBBER
30cm
IRON PIPE ¾" GALVANIZED, TOTAL LENGTH 120 CM.
PRESSURE TANK GALVANIZED IRON
¼ INCH PIPE SOLDERED TO TANK
¼ INCH HOSE
3/16" BOLT
SOLDER
2cm
TANK FLANGE BARREL METAL
RUBBER GASKET
PIPE FLANGE
2 cm
WOODEN HANDLE
3cm
10 cm

FIG 2
PUMP CROSS SECTION

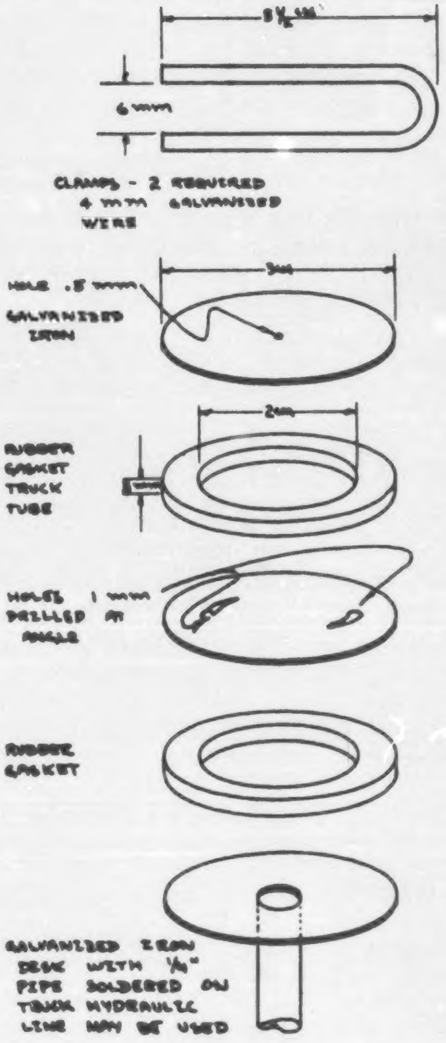

3½ cm
6 mm
CLAMPS - 2 REQUIRED 4 mm GALVANIZED WIRE
3cm
HOLE .5 mm
GALVANIZED IRON
2cm
RUBBER GASKET TRUCK TUBE
HOLES 1 mm DRILLED AT ANGLE
RUBBER GASKET
GALVANIZED IRON DISK WITH ¼" PIPE SOLDERED ON TANK HYDRAULIC LINE MAY BE USED

FIG. 3
DISK NOZZLE

The length of the hose can be determined by the maker of the sprayer but should be about 4 meters to allow the man doing the spraying to cover quite a large area before having to move the bucket. Also, the length of the small pipe and the angle of the spray nozzle will be determined by the kind of crops being sprayed.

At times it will be necessary to "prime" the sprayer pump. This is caused by two things. Either the valve rubber is too tight and the air cannot be forced through the valve, or the rubber is stuck to the pipe. To prime the pump turn it up-side-down and fill the pipe with water. Holding the thumb over the pipe, turn the pump over and lower it into the bucket of liquid and start pumping in the usual manner. If priming does not start the pump it will then be necessary to remove the pressure tank to inspect and repair the valve.

Only very clean water should be used to make the mixture for spraying and it should be strained through a cloth after mixing to remove any particles which might cause the nozzle to plug. If a very fine brass screen is available, it should be put in the nozzle to keep the dirt from plugging the holes.

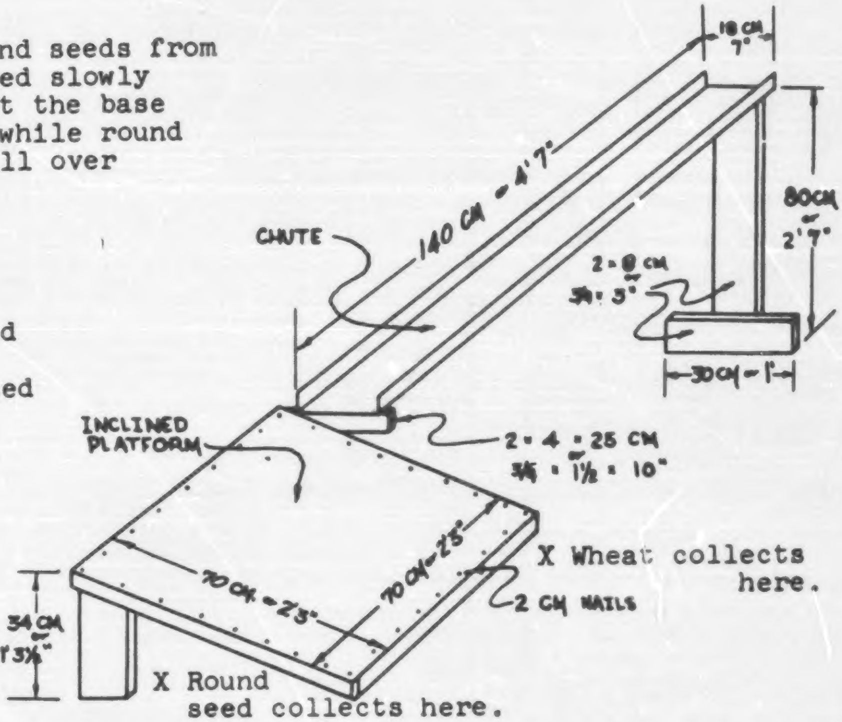
GRAIN CLEANER

ABSTRACT

This device removes round seeds from wheat. Sieved grain poured slowly down the chute collects at the base of the inclined platform while round seeds, rolling faster, fall over the far side.

TOOLS AND MATERIAL

1 - 70 x 70 cm. galvanized iron
1 - 24 x 140 cm. galvanized iron
4 - 2 x 4 x 68 cm. wood
1 - 2 x 4 x 25 cm. wood
1 - 2 x 8 x 80 cm. wood
1 - 2 x 8 x 30 cm. wood
1 - 2 x 8 x 34 cm. wood
Hammer, saw, nails.



X Wheat collects here.

X Round seed collects here.

BAMBOO POULTRY HOUSE

ABSTRACT

This bamboo poultry house has a thatch roof and slat walls to provide good ventilation. The elevated slat floor keeps chickens clean and healthy while the egg catch and feed troughs simplify maintenance.

TOOLS AND MATERIALS

Bamboo
Nails
Thatching materials
Small tools

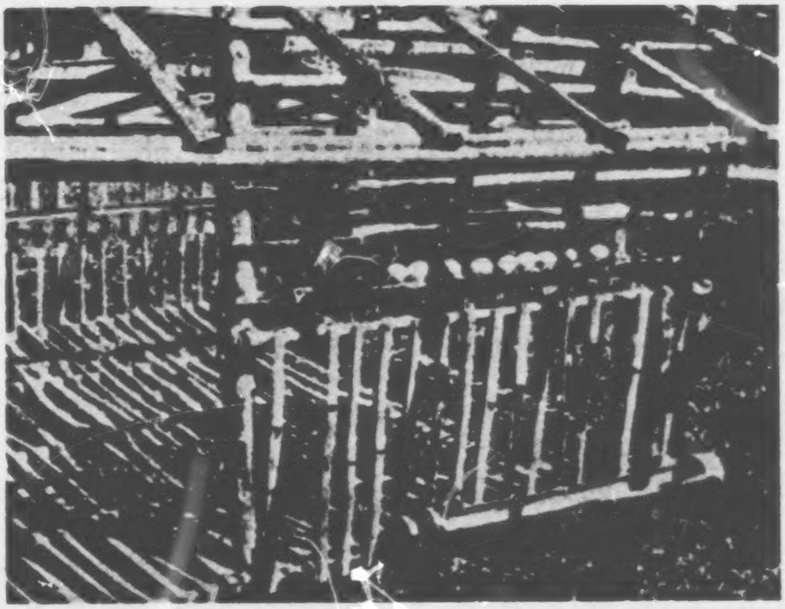


FIG. 1 SHOWS EGG CATCH AND FEED TROUGH

DETAILS

The house is built on a frame of small poles, with floor poles raised about 3 feet from the ground. The floor poles are covered with large bamboo stalks, split into strips 1 1/2" wide, spaced 1 1/2" apart. Floors so constructed have several advantages: better ventilation, no problem of wet moldy litter during rainy season or dry dustry litter during dry season; droppings fall between split reeds to ground away from chickens. This eliminated parasites and diseases normally passed from hen to hen through droppings remaining warm and moist in litter. However, it has been suggested that wide spacing of floor and wall slats might invite marauders such as weasels and snakes.

Walls are constructed from vertical strips of bamboo 1 1/2" wide, spaced 2 1/2" to 3" apart. This also allows ample ventilation, needed to furnish oxygen to the chickens and to allow evaporation of excess moisture produced in the droppings. In the tropics the problem is to keep chickens cool, not warm. Using a closed or tight-walled poultry house with a solid floor would keep them too warm and result in lowered production and increased respiratory problems.

The roof must protect the chickens from the weather. In Liberia thatch roofing keeps the birds cool, but it must be replaced more often than most other materials. Since it is cheap and readily available to the small farmer or rural family, it is most likely to be used. Aluminum, which reflects the heat of the sun, and asbestos, an efficient insulator, are desirable roofing materials in the tropics. Zinc, which is commonly used to roof houses in Liberia, is undesirable for chicken houses because it is an efficient conductor of heat.

Whatever the roofing material, the roof must have an overhang of of 3' on all sides to prevent rain from blowing inside the house. It may be desirable to slope the overhang toward the ground.

Feeders and waterers are made from 4 to 5" diameter bamboo of the desired length. A node or joint must be left intact in each end of the bamboo section to keep the feed or water in. A section 3 to 4" wide around half the circumference of the bamboo, except for 3" sections on the ends, is removed to make a kind of trough. All nodes between the ends are removed. These feeders must be fastened at the base, to keep them from rolling.

The feeders are fastened to the outside of the walls about 6" above floor level. The hens place their heads through the bamboo strips to feed or drink, thus conserving floor space for additional chickens.

In laying houses nests are also constructed of split bamboo for unobstructed ventilation. Conventional lumber nests are hotter and may result in hens laying eggs on the floor instead of in the nests. This means more dirty eggs, more broken eggs, and more likelihood of the hens eating the broken eggs. The only way to cure a hen of eating eggs once the habit is formed, is to kill her. In addition, as the hens enter the nests they sit on eggs laid previously by other hens, keeping them warm. The quality of eggs deteriorates very fast under these conditions.

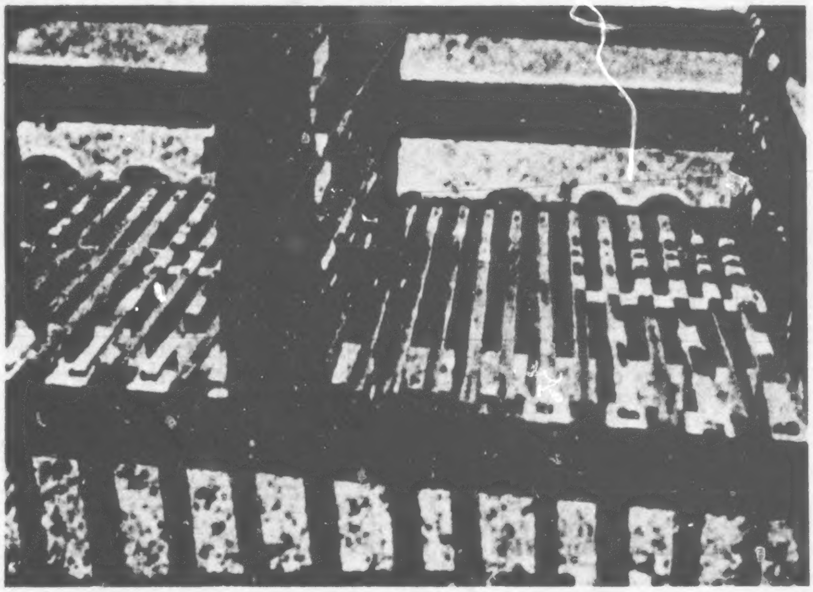


FIG. 2 NESTS IN BAMBOO POULTRY HOUSE

The demonstration nests are 15" long, 12" wide, and 14" high. The strips used on the floor of the nest are about 1/2" wide, spaced 1/2" apart, and must be very smooth. The floor slopes 1/2" from front to back, so that when the eggs are laid they will roll to the back of the nest. An opening 2" high at the back of the nest allows the eggs to roll out of the nest into an egg catch. This type of nest results in less egg breakage, cleaner eggs, better quality eggs, because they begin to cool as soon as they roll out of the nest. In addition, the eggs are outside the nest where egg eating hens cannot reach them. Placing the egg catch so it protrudes outside the wall of the house allows the eggs to be gathered from outside. Placing the nests 3' above the floor conserves floor space and permits more laying hens to be placed in the laying house. One nest is put in for every five hens.

EVALUATION

The poultry house costs nothing but labor to build and is certain to produce healthier, more productive chickens. It has been used successfully in the Philippines and Liberia.

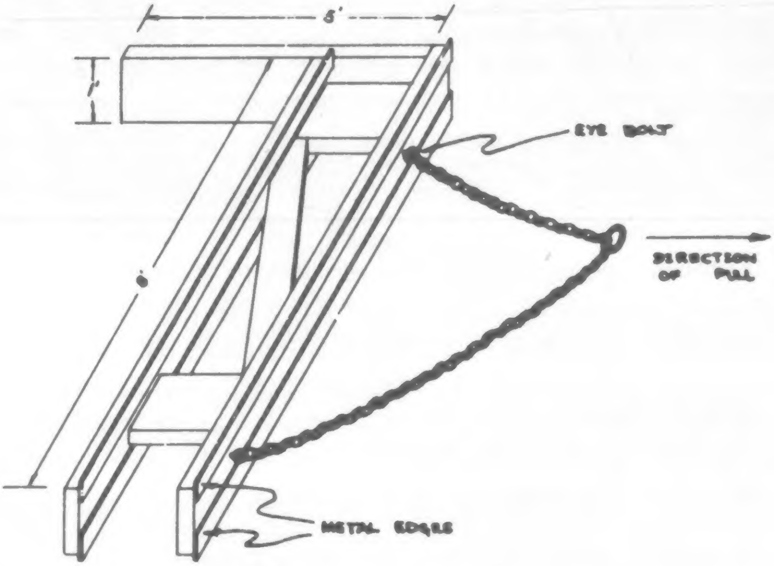
DRAG GRADER

ABSTRACT

This simple metal edged wooden grader is designed for two medium sized work horses or oxen.

TOOLS AND MATERIALS

3" x 12" lumber
  2 pieces 8' long
  1 piece 5' long
  2 pieces 1' long
3" x 6" lumber
  1 piece 4 1/2' long
4 metal edges 1/4" to 1/2" thick, 4" wide, 8' long.
17 lag screws 7" long, 5/8" diameter.
2 eye bolts, 3" diameter eye large washers
12 feet heavy chain
32 woodscrews, 3" flat-head steel.

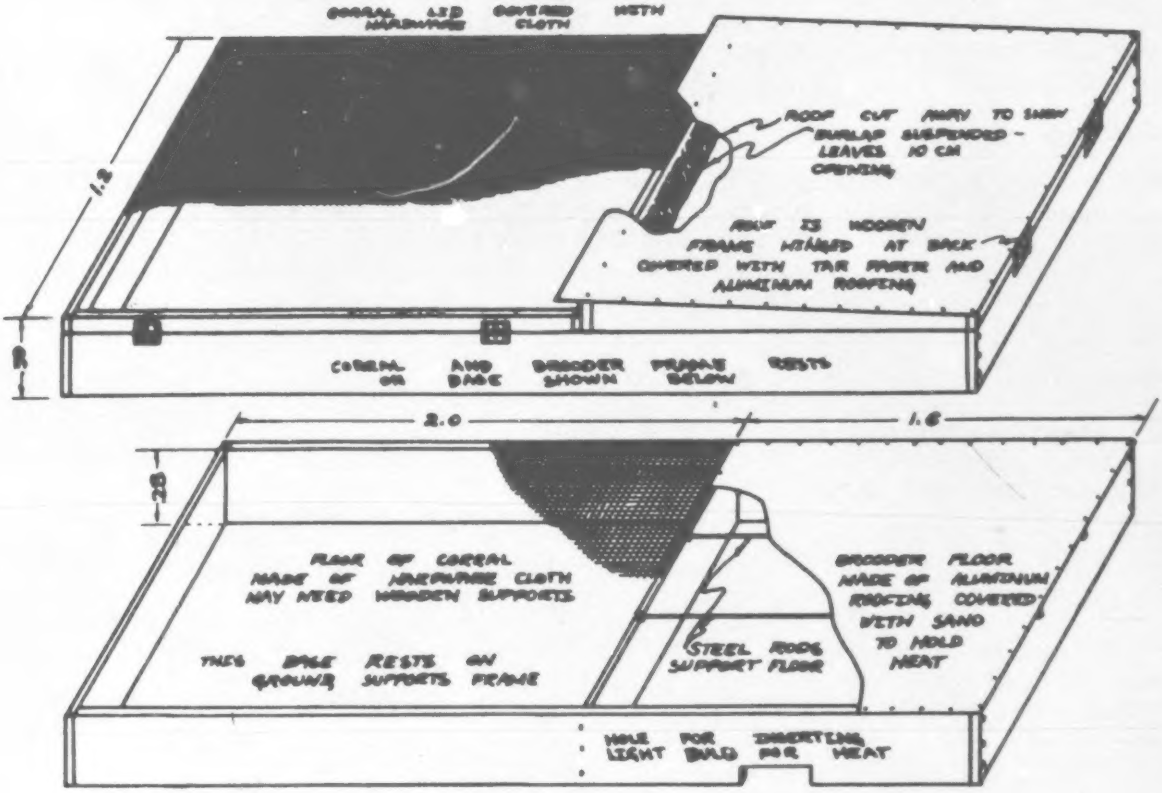


DETAILS

The angle between the 5' and 8' beams should be made 30° if ditch cleaning is anticipated. The unit can be scaled down for use with one animal. The metal edge overhangs the surfaces of the 8' beam by one inch. Each is screwed on with eight large woodscrews or carriage bolts.

The position of the scraper is adjusted by changing the hitching point on the chain. The metal edges are attached to both top and bottom so the drag can be turned over to reverse the direction in which material is cast.

CHICKEN BROODER


CORRAL LID COVERED WITH HARDWARE CLOTH
ROOF CUT AWAY TO SHOW BURLAP SUSPENDED - LEAVES 10 CM OPENING
ROOF IS WOODEN FRAME HINGED AT BACK COVERED WITH TAR PAPER AND ALUMINUM ROOFING
1.2
CORRAL AND BROODER FRAME RESTS ON BASE SHOWN BELOW
2.0
1.6
28
FLOOR OF CORRAL MADE OF HARDWARE CLOTH MAY NEED WOODEN SUPPORTS
THIS BASE RESTS ON GROUND SUPPORTS FRAME
STEEL RODS SUPPORT FLOOR
BROODER FLOOR MADE OF ALUMINUM ROOFING COVERED WITH SAND TO HOLD HEAT
HOLE FOR INSERTING LIGHT BULB FOR HEAT

ABSTRACT

This brooder is sufficient size for 200 chicks, and is hinged for easy access to corral and brooder. Dimensions are shown in meters.

TOOLS AND MATERIALS

Hardware cloth 1.2 x 2 m., 2 pieces this size needed.
Aluminum roofing - 1.2 m. x 1.6 m., 1.2 m. x 1.7 m.
Wood, approximately 30 cm x 2 cm x 20 m..
Steel rod 1 cm diameter x 3.2 m.
4 hinges about 8 cm long
Woodscrews for hinges
2 buckets clean dry sand
Nails, tacks, staples
Small tools

DETAILS

This chick brooder is heated by a regular electric light bulb, placed under the brooder floor. Sand placed on the floor of the brooder holds and distributes the heat, and helps keep the area clean and dry. Depending on the temperature rise required, the wattage of the light bulb will have to be chosen by experimentation. The metal floor and roof prevent predators such as rats from entering the brooder. If electric power is not available, an excavation can be made for a lantern. Be sure the lantern has adequate ventilation.

EVALUATION

This type of brooder has been used successfully in Ecuador and other places by the indigenous people to raise broilers for a cash crop.

EARTH BORER

ABSTRACT

This simple, lightweight inexpensive earth borer developed in India can be used for digging postholes, latrine holes, and in fact any hole with a diameter from 8" to 23" or even larger. It works well only in certain types of soil.

TOOLS AND MATERIALS

Earth Borer - a similar earth borer, the Ulti-Balti, is manufactured by the Agricultural Development Society, P.O. Naini, Allahabad, U.P., India - only the cutting head is supplied for about Rs. 17, nP. 25, or about $6.00. It weighs 3 1/2 Seers, or 7.2 pounds, f.o.b. factory.
Bamboo pole - 15' to 18' long, smooth and straight, 1 1/2" diameter maximum.
Barrel metal 23" x 9" for blade, but tough steel 1/16" thick is better.
Strap iron - 2 pieces 1/4" x 1" x 11"
Machine bolts - 2, 3/8" x 2" with nuts and lockwashers for attaching handle to straps.
Machine bolts - 4, 3/8" diameter x 3/4" long with nuts and lockwashers for attaching straps to blade.
Iron rivets - 8, 1/4" diameter x 3/8" long to fasten ends of blade together.
Drill - with 1/4" and 3/8" bits
Hammer and anvil
Wrench
Heavy tinsnips
File

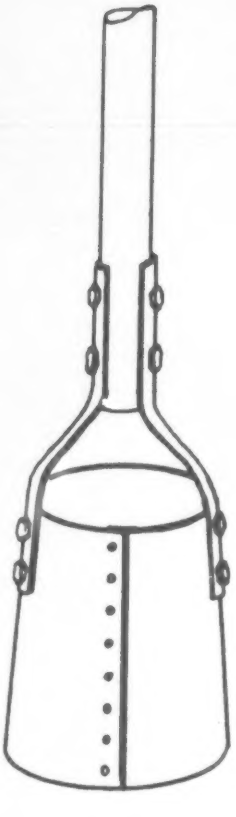
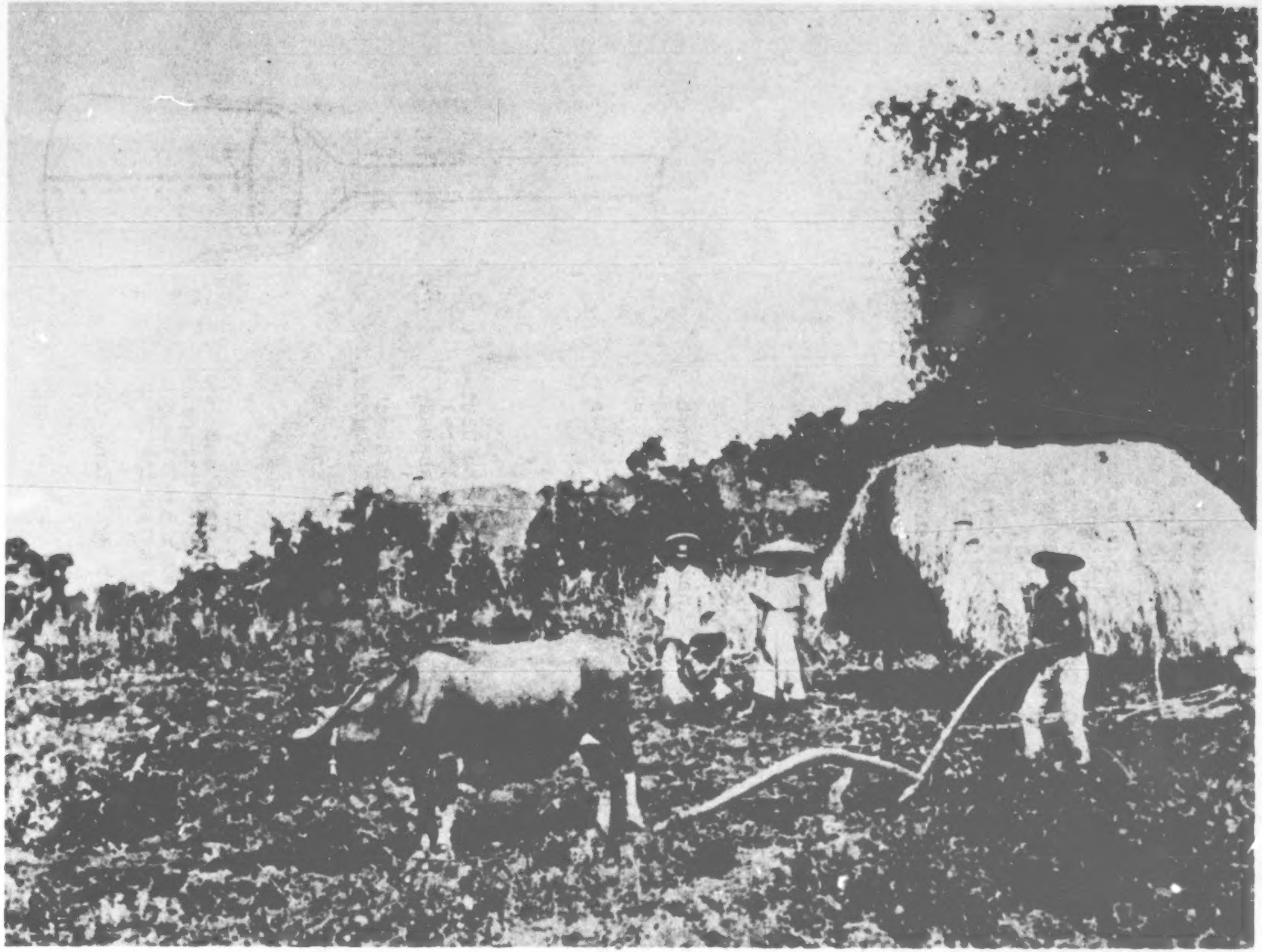


FIG 1



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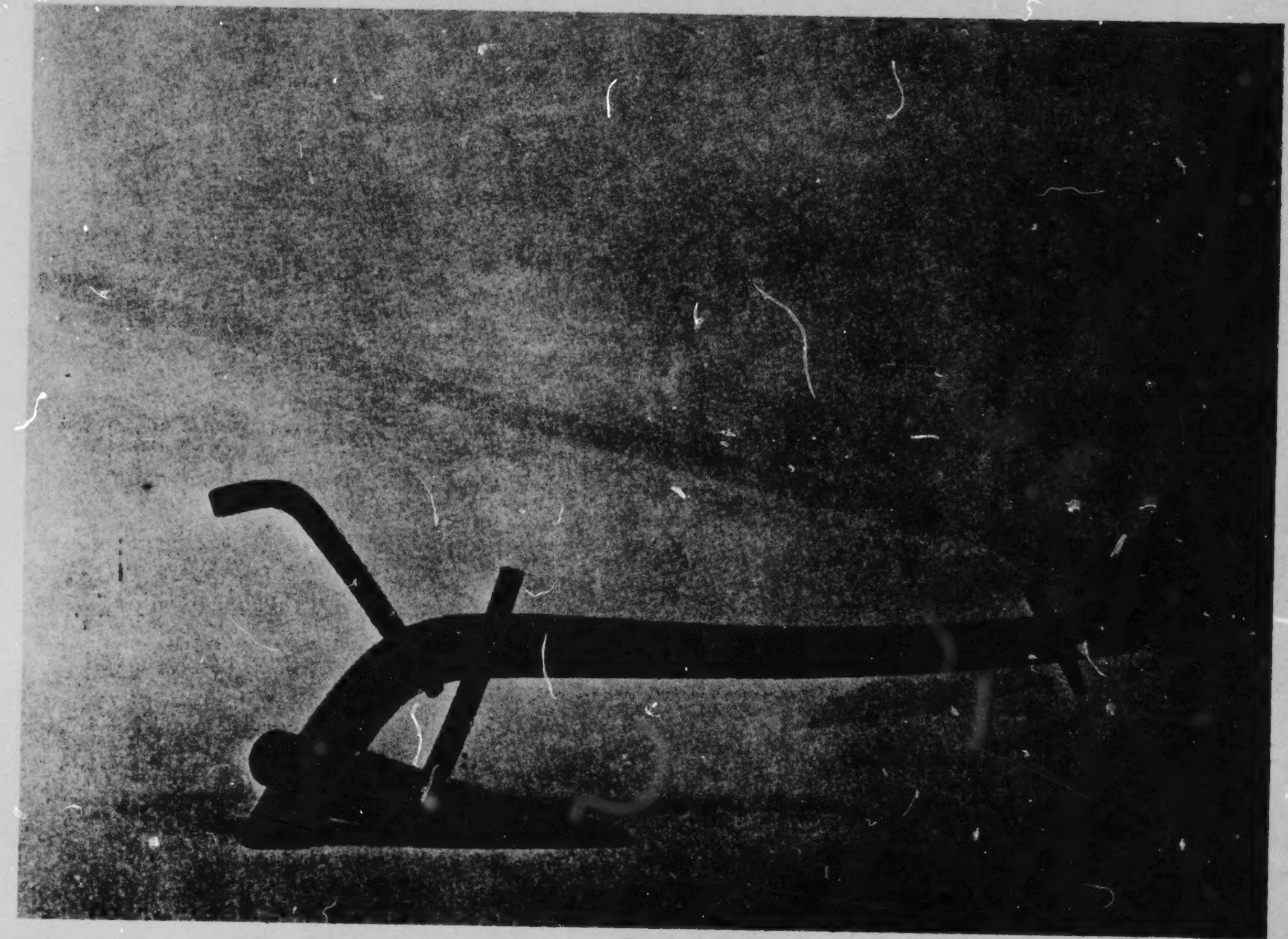

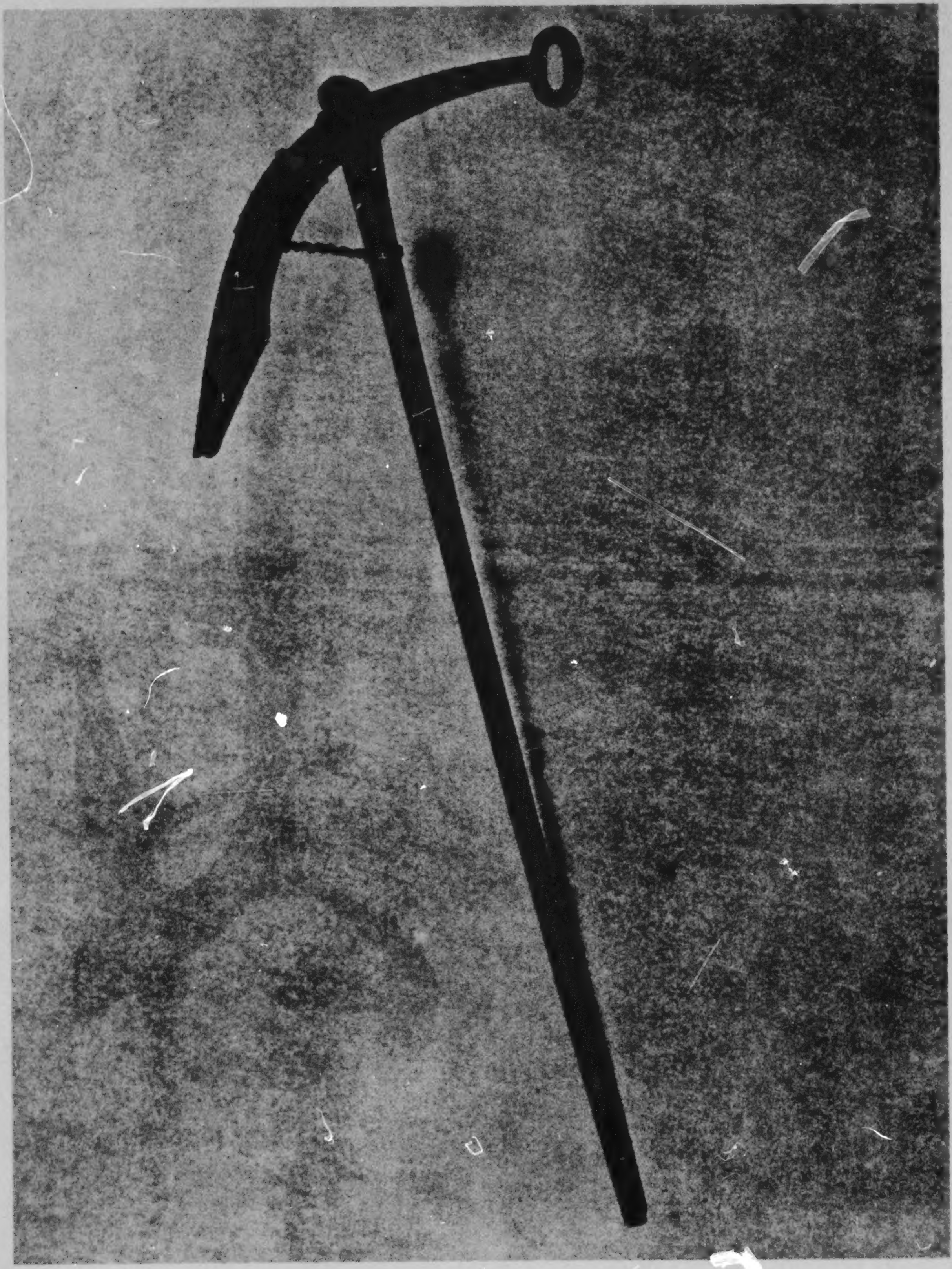

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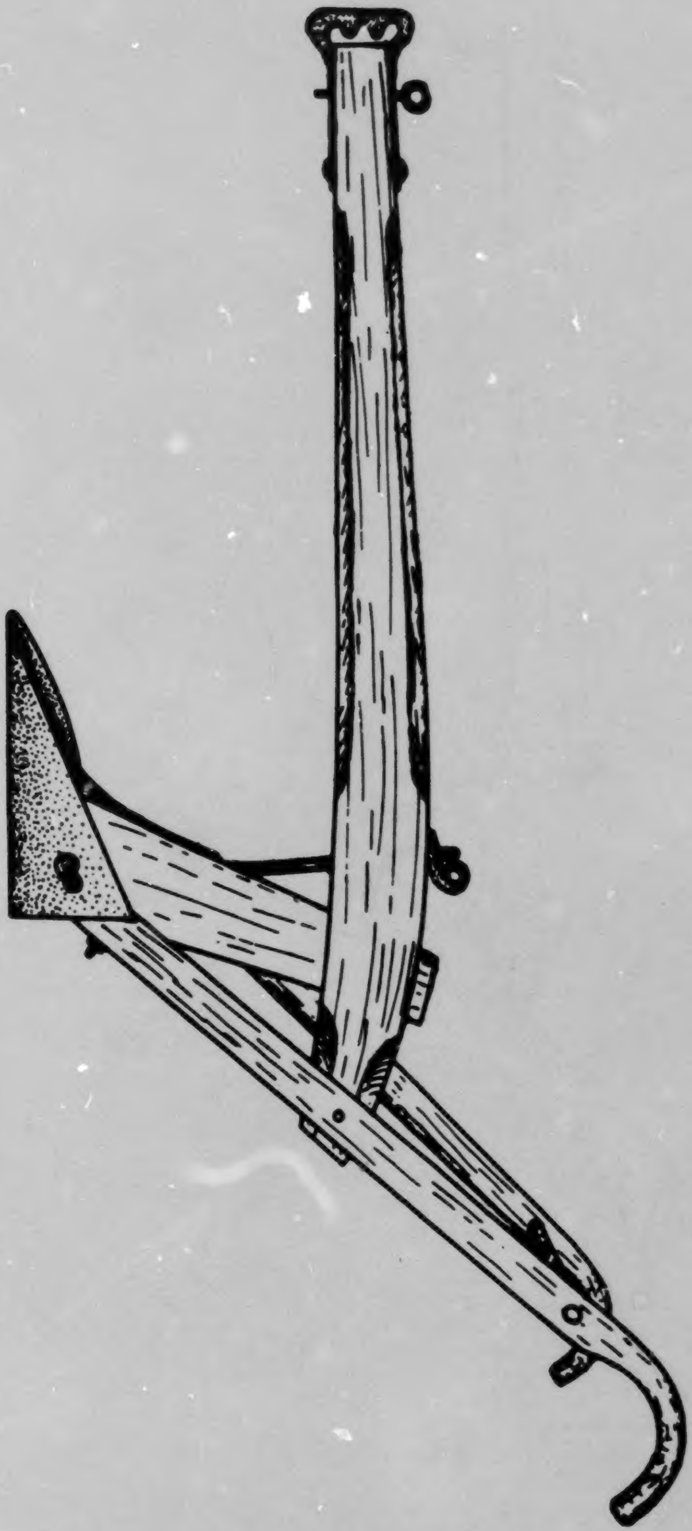

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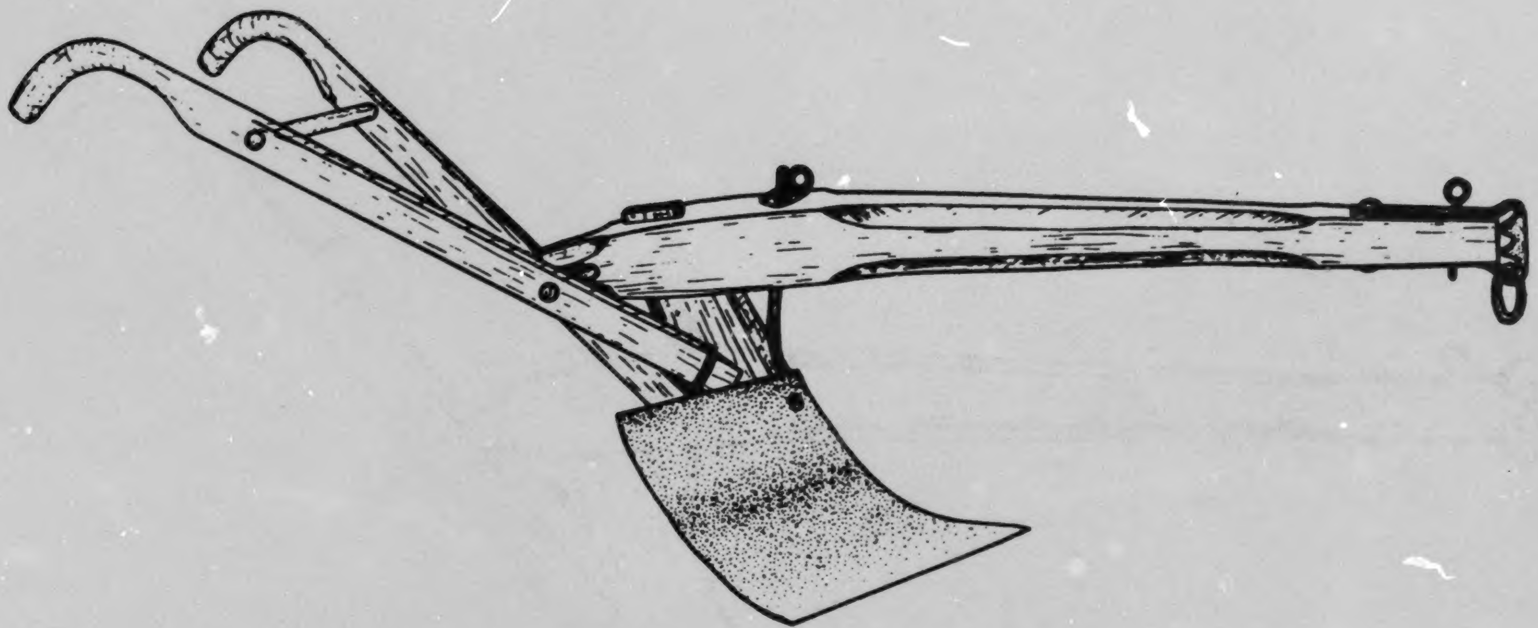

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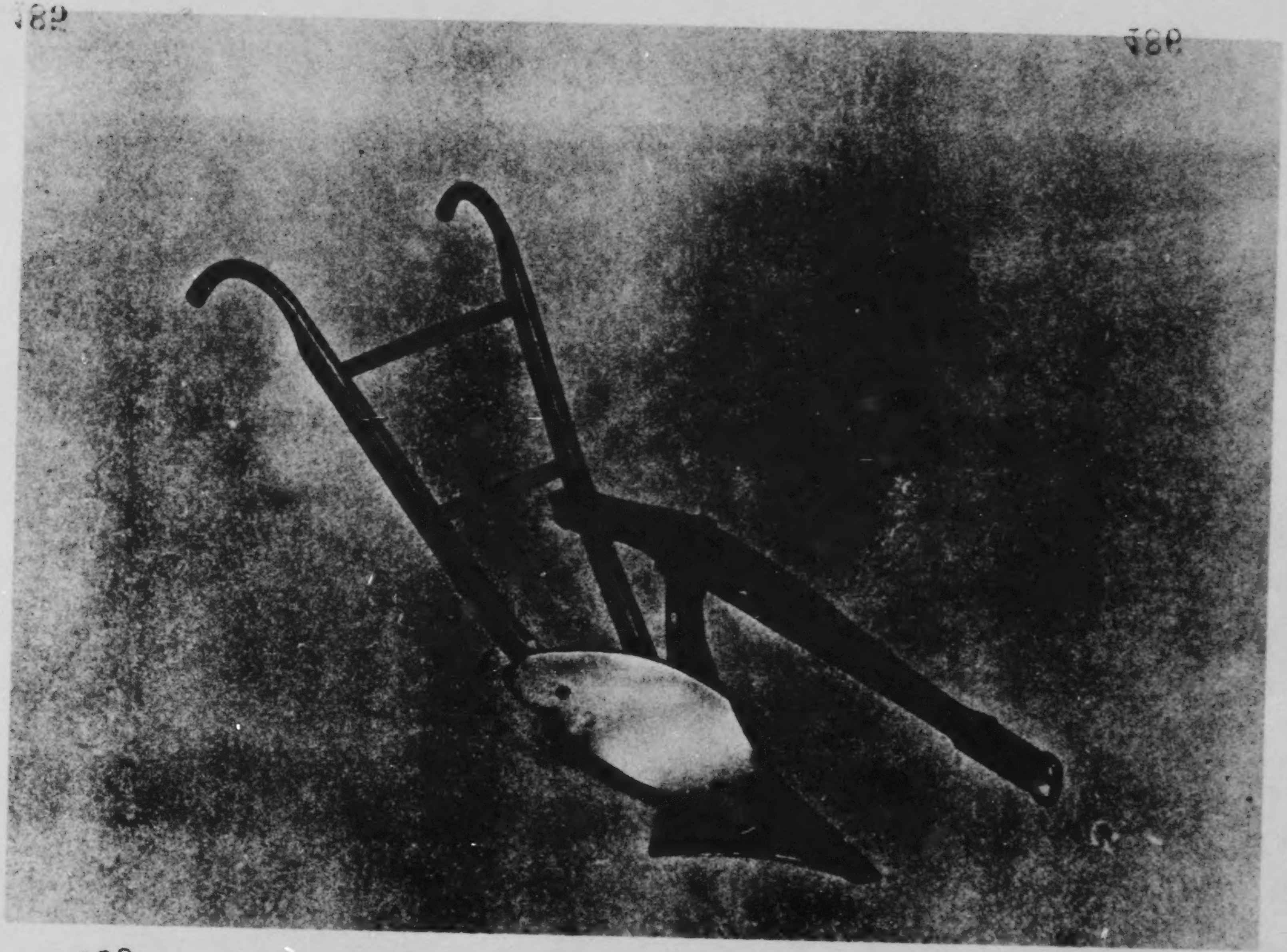

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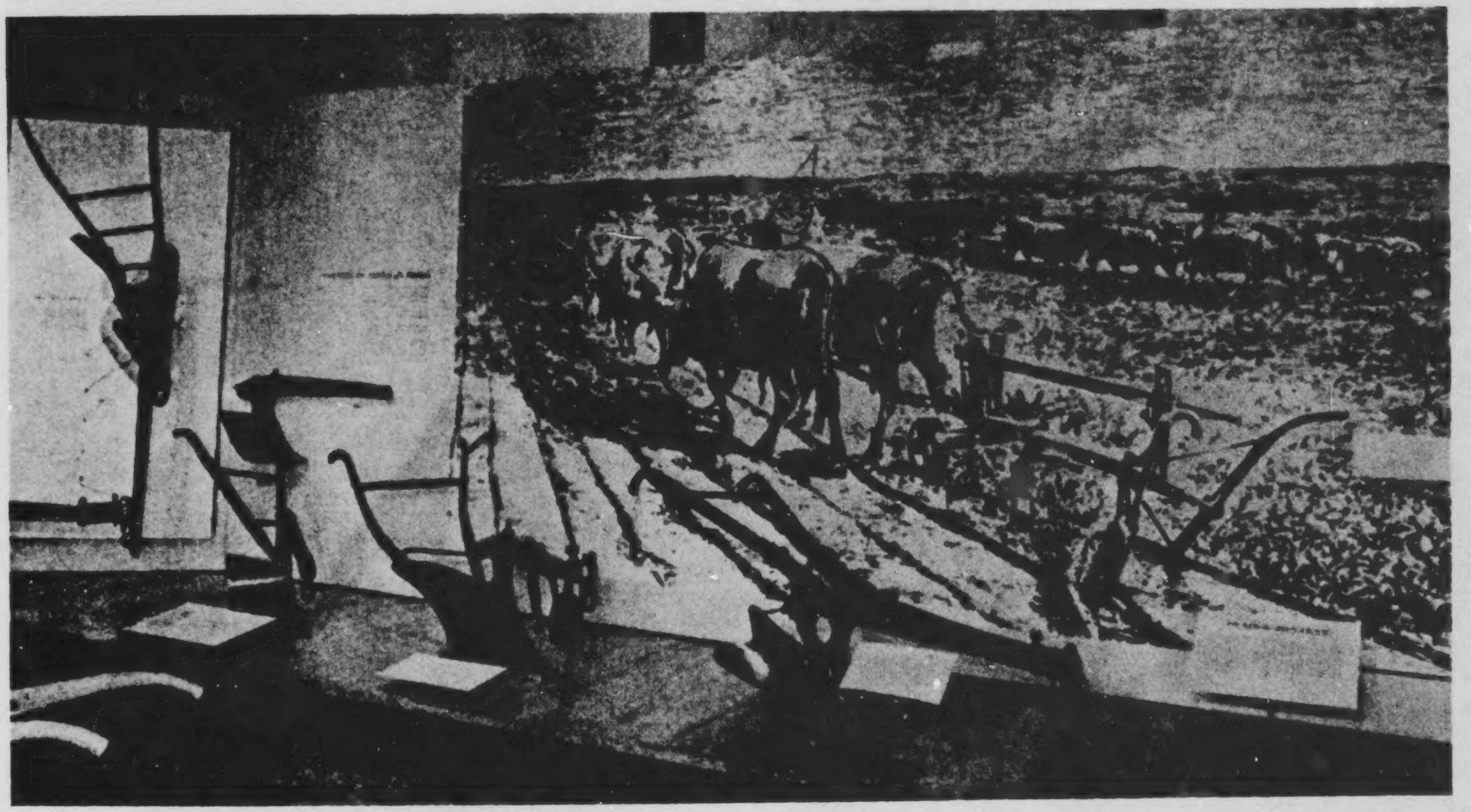
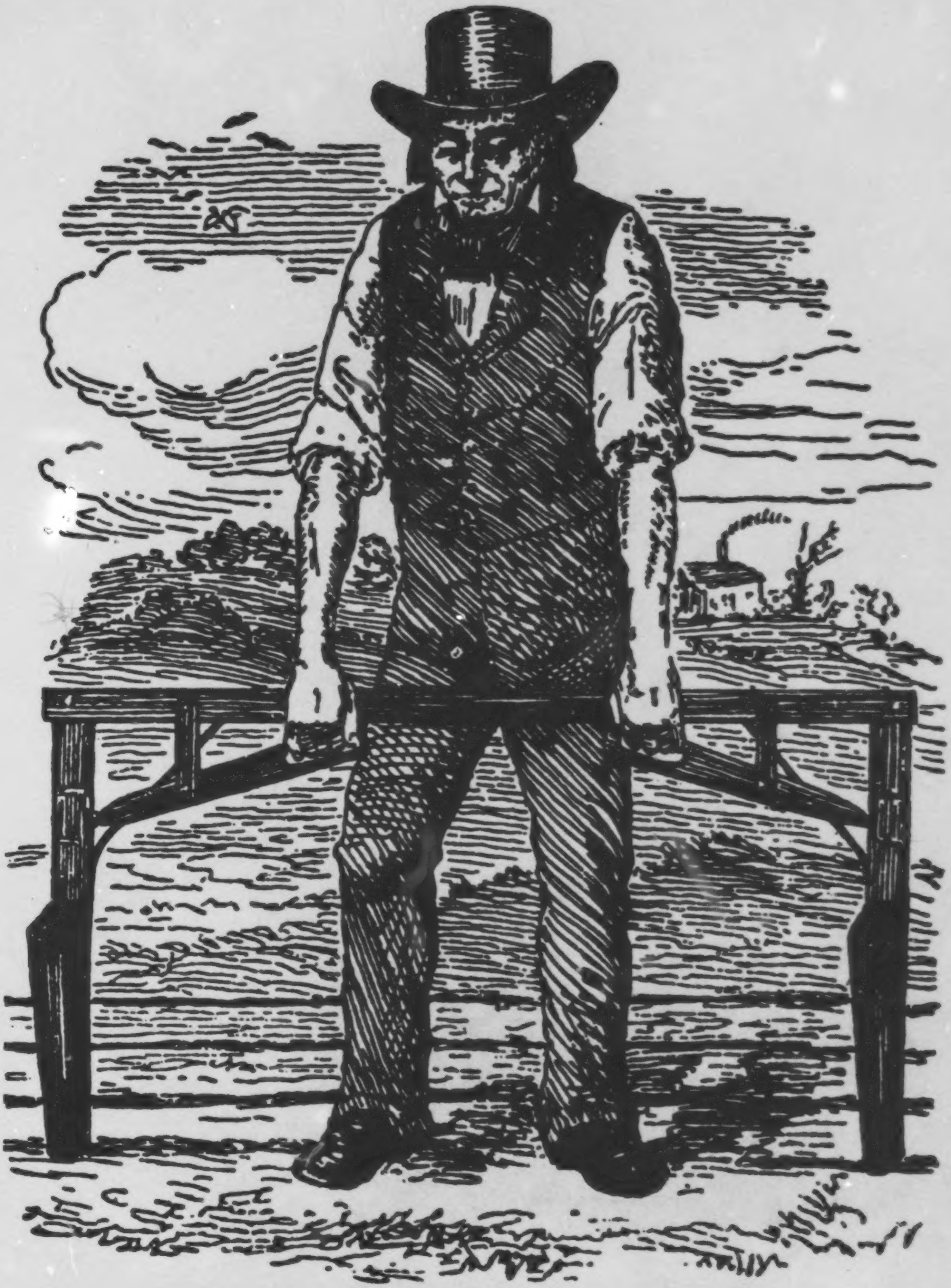
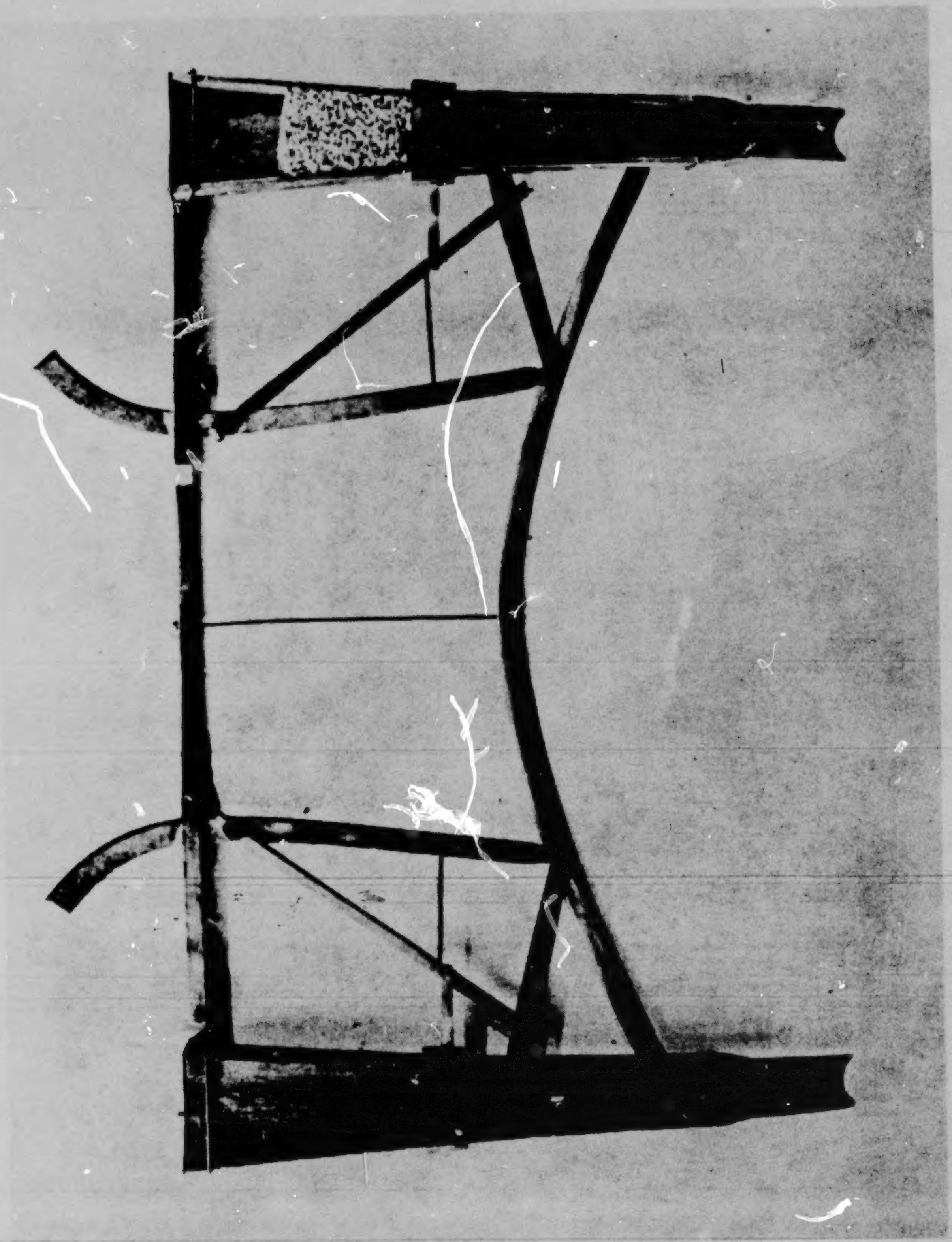
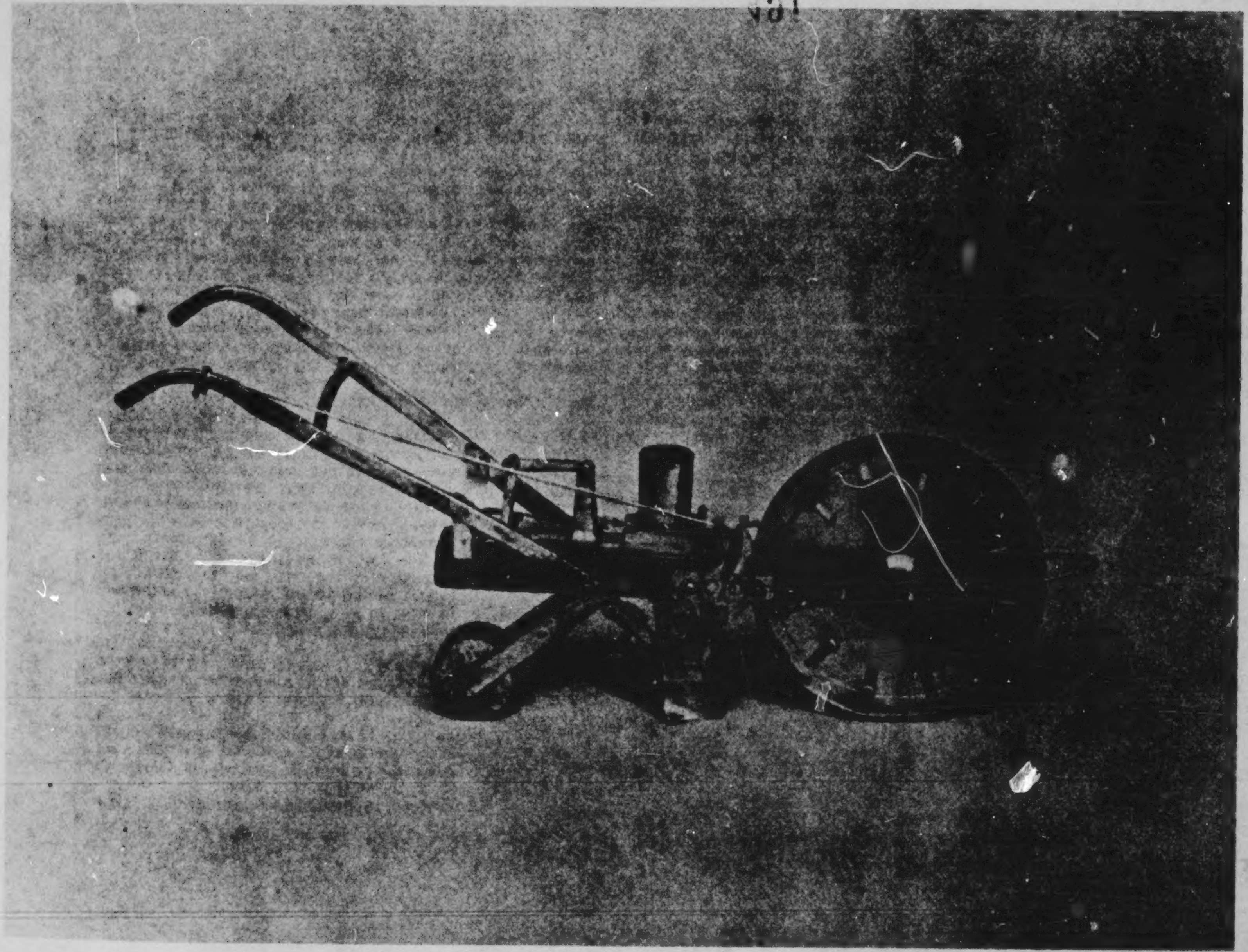
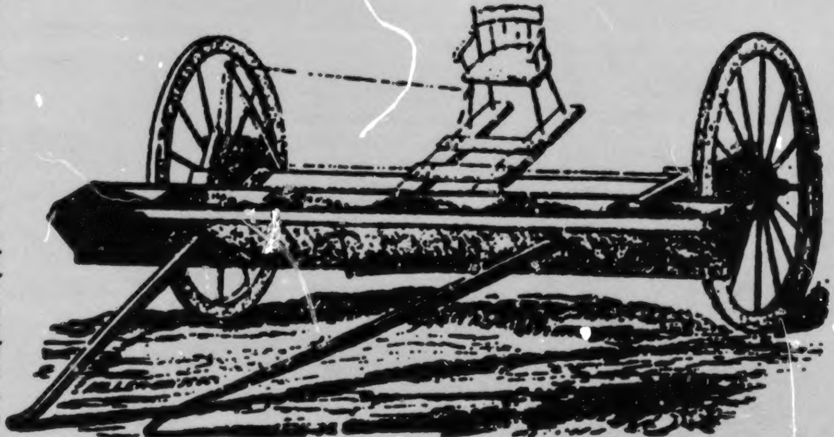








Seymour's Patent Broad Cast Sowing Machine.



THIS machine was patented in 1845 and ten years have proved it to be unequalled in the United States for the purposes for which it is designed. It is durable, having but very little machinery to perform, as follows:

It sows correctly all kinds of grain, (and any desired quantity per acre,) from peas to grass seed, including wheat, rye, oats, barley, buckwheat, rice, hemp, flax, clover and timothy seed,—also, plaster, lime, salt, ashes, bone dust, &c., &c. It is capable of dusting every inch of ground on an acre of land, with less than half a bushel of plaster, and thirty or forty bushels of lime may be thus evenly applied to the same amount of land. It sows ten feet wide, or may be made narrower to order. It has received the highest recommendations from hundreds of the best farmers in our country, and received eight premiums from Agricultural Societies, besides the highest Prize and Diploma at the trial of Agricultural Implements, held at Geneva, July, 1852.

The following is from the Albany Cultivator of June, 1848, by the editor, Mr. L. Tucker:

"This cut represents Seymour's Sowing Machine, advertised in our last. It has been extensively used in [illegible] tern N. Y., and is much approved. We saw many [illegible] kinds of grain on the farm of John Delafield, [illegible] va, last season, which had been sown with this machine, and we never saw grain stand more evenly on the ground. Mr. Delafield assured us that he could sow anything—lime, plaster, poudrette, guano, &c., or any seed from grass seed to peas, or Indian corn, with perfect exactness, graduating the quantity per acre to a pint."

Reference is also made to all the Presidents of the New York State Agricultural Society who have presided since 1845. ☞PRICE $55.

I purchased one of Mr. Seymour's Plaster Sowers in 1854, and it was used by myself and a neighbor in sowing thirty or forty tons of plaster. I purchased another in the Fall of 1854, and I am now using both. One hand with an ordinary horse can sow, without difficulty, twenty to twenty-five acres a day. The distribution is as perfect as possible. I am certain that every square inch of an acre was dusted by one-third of a bushel. My neighbor, Mr. F. K. Nelson, thinks he effected it with one peck. I cannot speak too highly of this machine as a plaster sower. It sows timothy seed and clover. I have not tried it with wheat, but feel assured it will answer well.

T. J. RANDOLPH.

ALBEMARLE, March 7, 1855.

☞Directions for using accompany each machine. All communications promptly attended to, and orders accompanied with current funds, immediately filled.

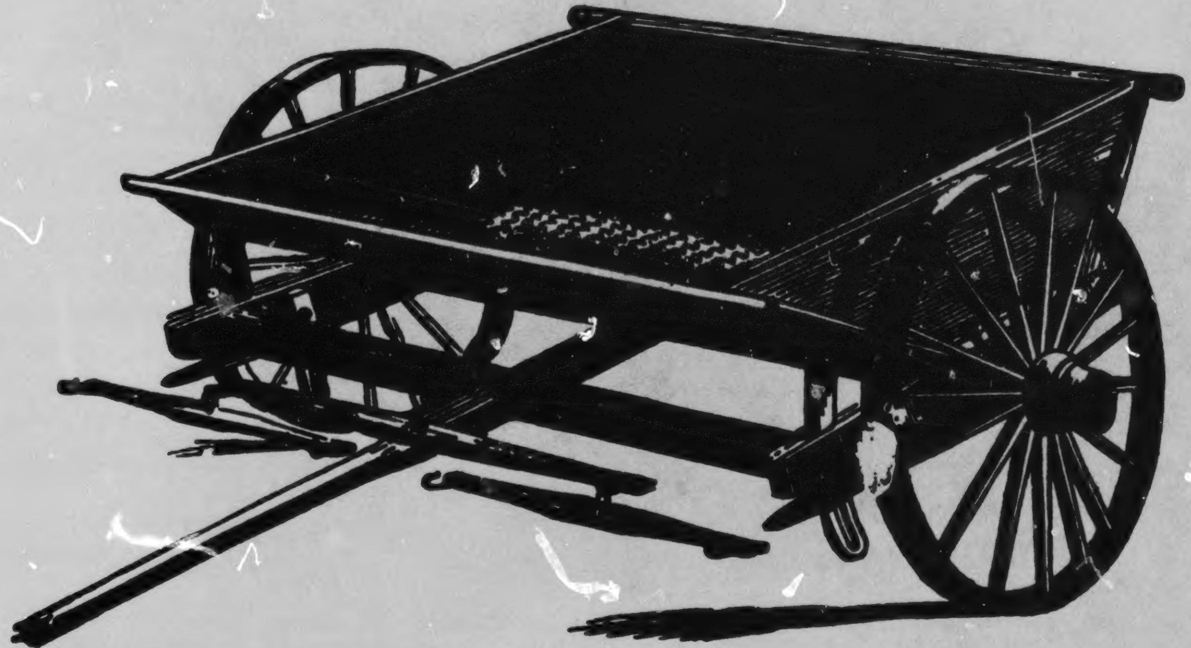
C. H. SEYMOUR, Manufacturer.
P. SEYMOUR, Patentee.

East Bloomfield, Ontario Co., N. Y.

☞Orders received at the office of the American Farmer for either of the above.
apr1-1t*

FURTHER IMPROVEMENTS.

COOPER'S PATENT LIME SPREADER!



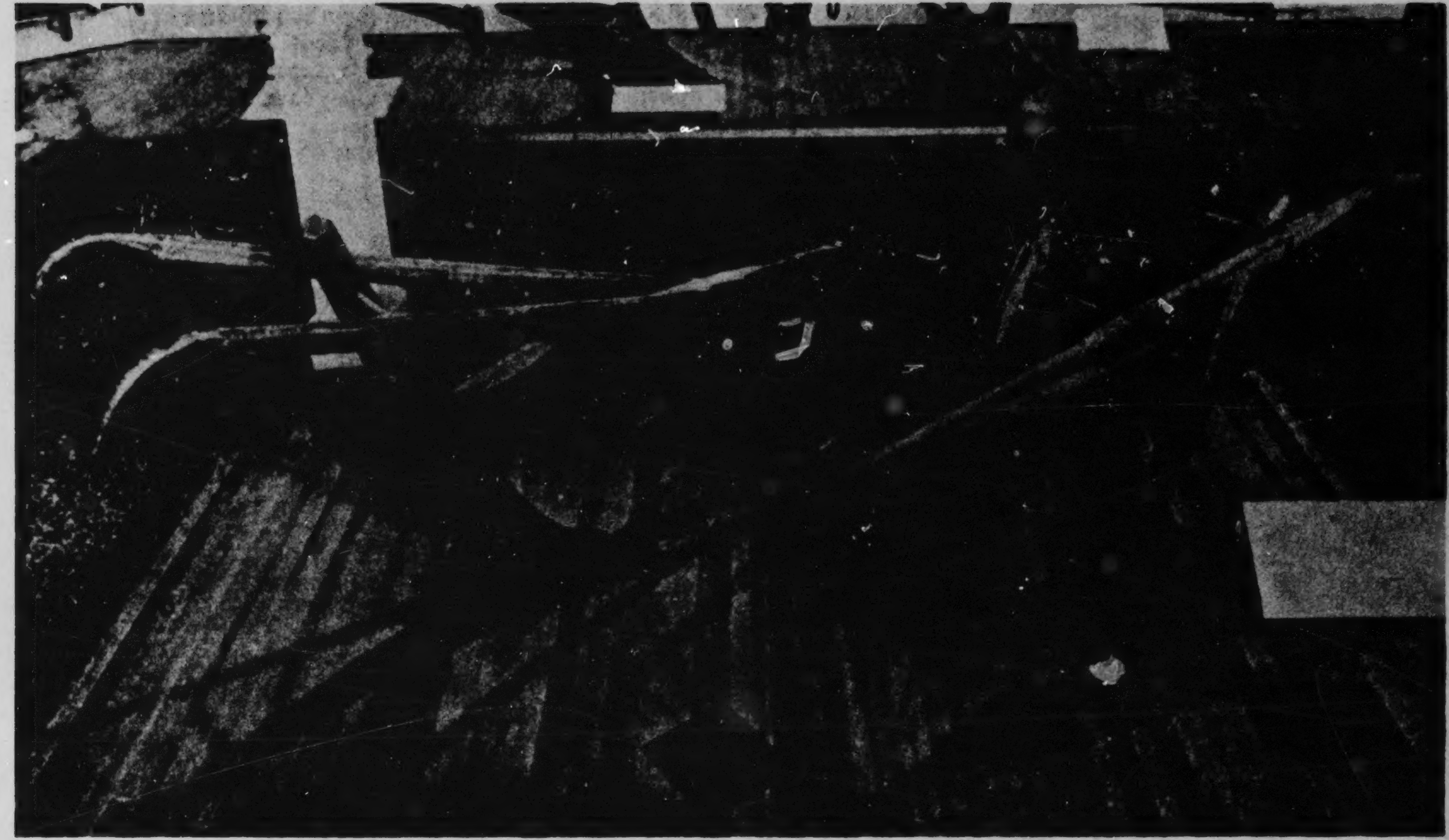
THAT has given such general satisfaction, and was fully described in the American Farmer last September and October, has been so improved that they can be used to spread lime in quantities varying per acre from 2 bushels up to 200; also to sow Guano in quantities from 150 lbs. to any desired amount upward. They will crush all hard lumps of Guano at the same time it is distributing, and with such accuracy that in no other way can be excelled. Price $75.

He also makes machines exclusively for sowing Guano, Super-phosphate and other chemical Fertilizers, that are much lighter and cheaper, but will make as even work, and as speedy. Price $75.

All orders addressed to LEWIS COOPER, the Patentee, at Christiana P. O., Lancaster Co., Pa., will meet with prompt attention.

sep1-3t

Cooper's Patent Lime & Guano Spreaders. | **FARMERS AND PLANTERS DEPOT,**
N. E. Corner 7th and Market St., Philadelphia.



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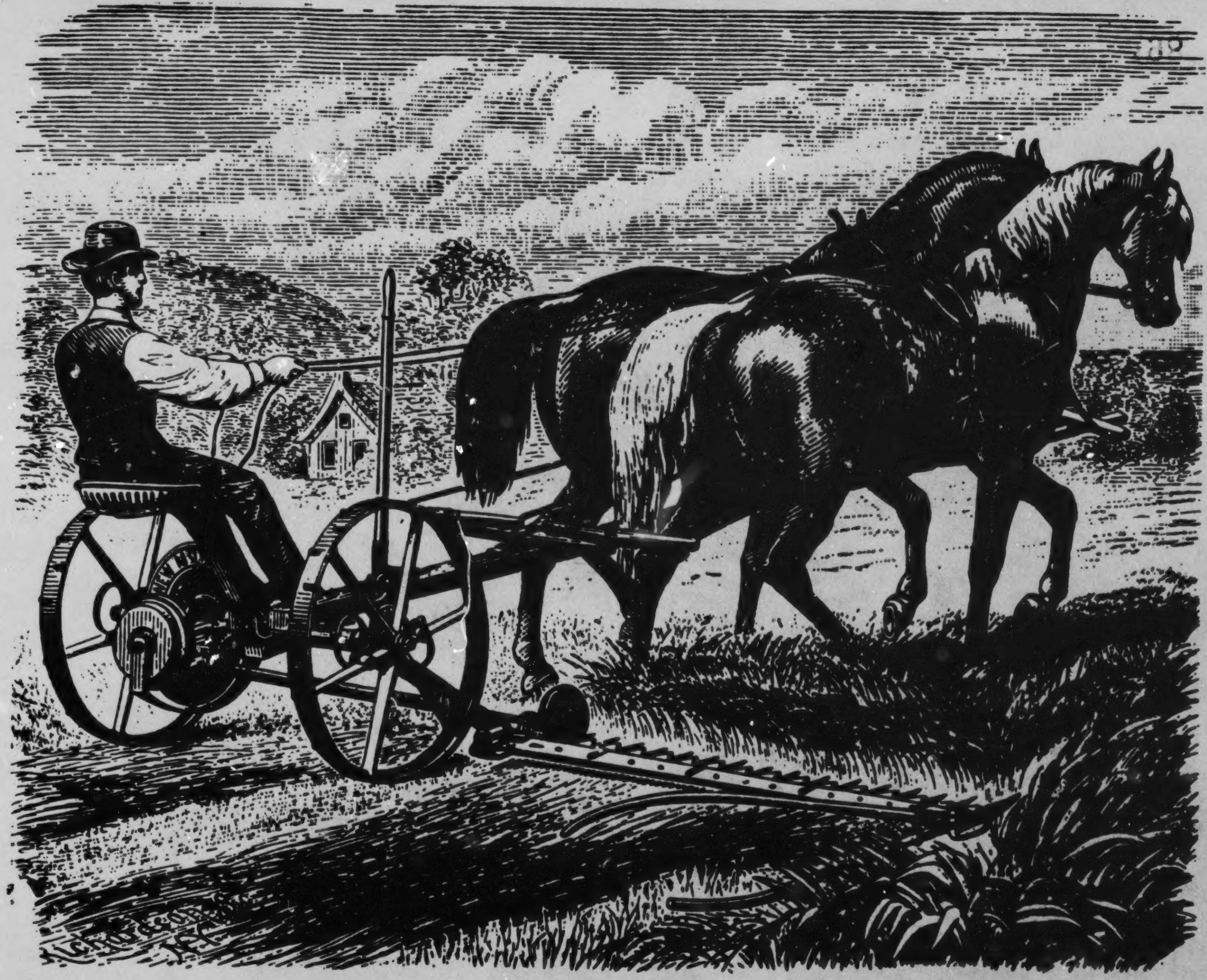

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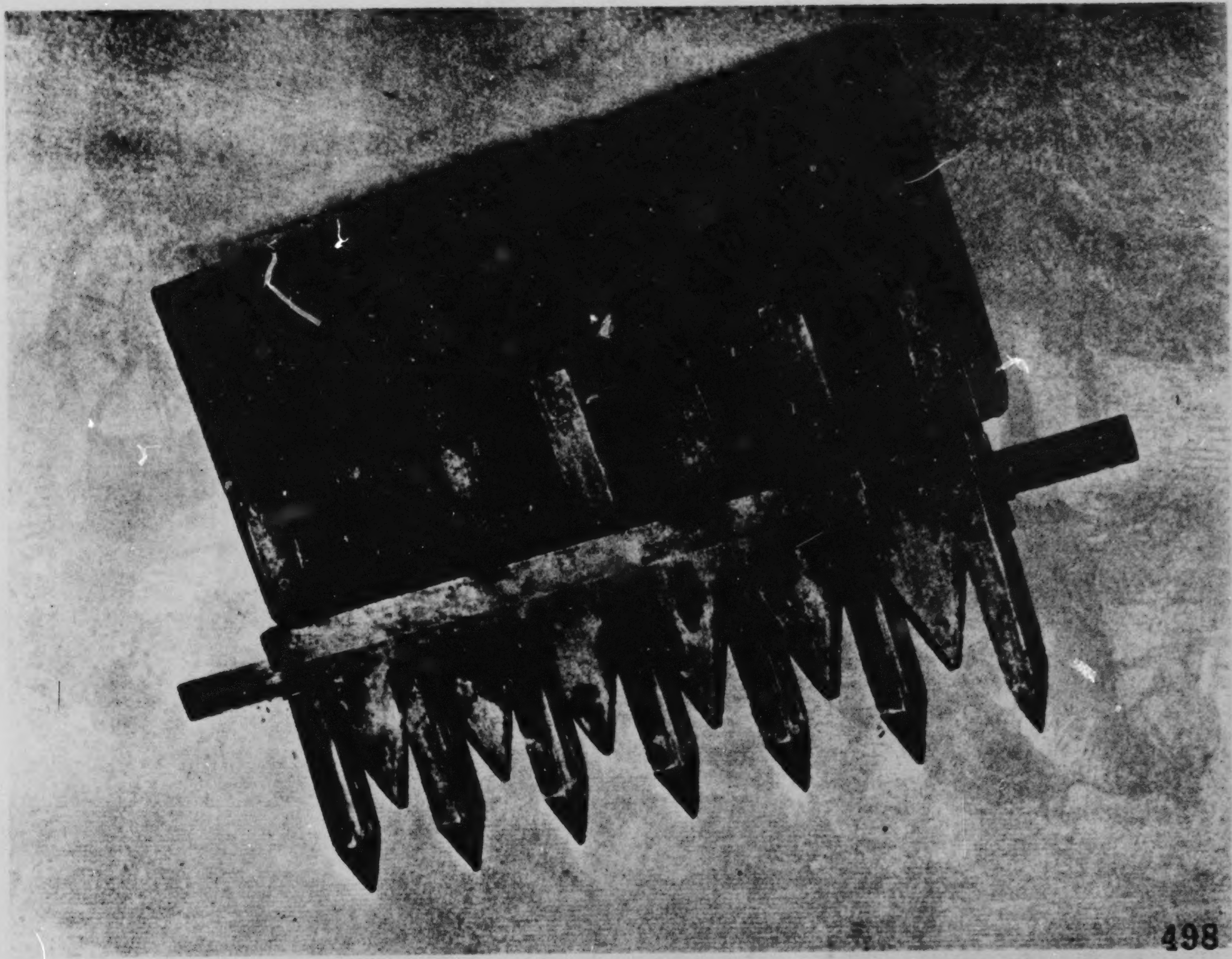

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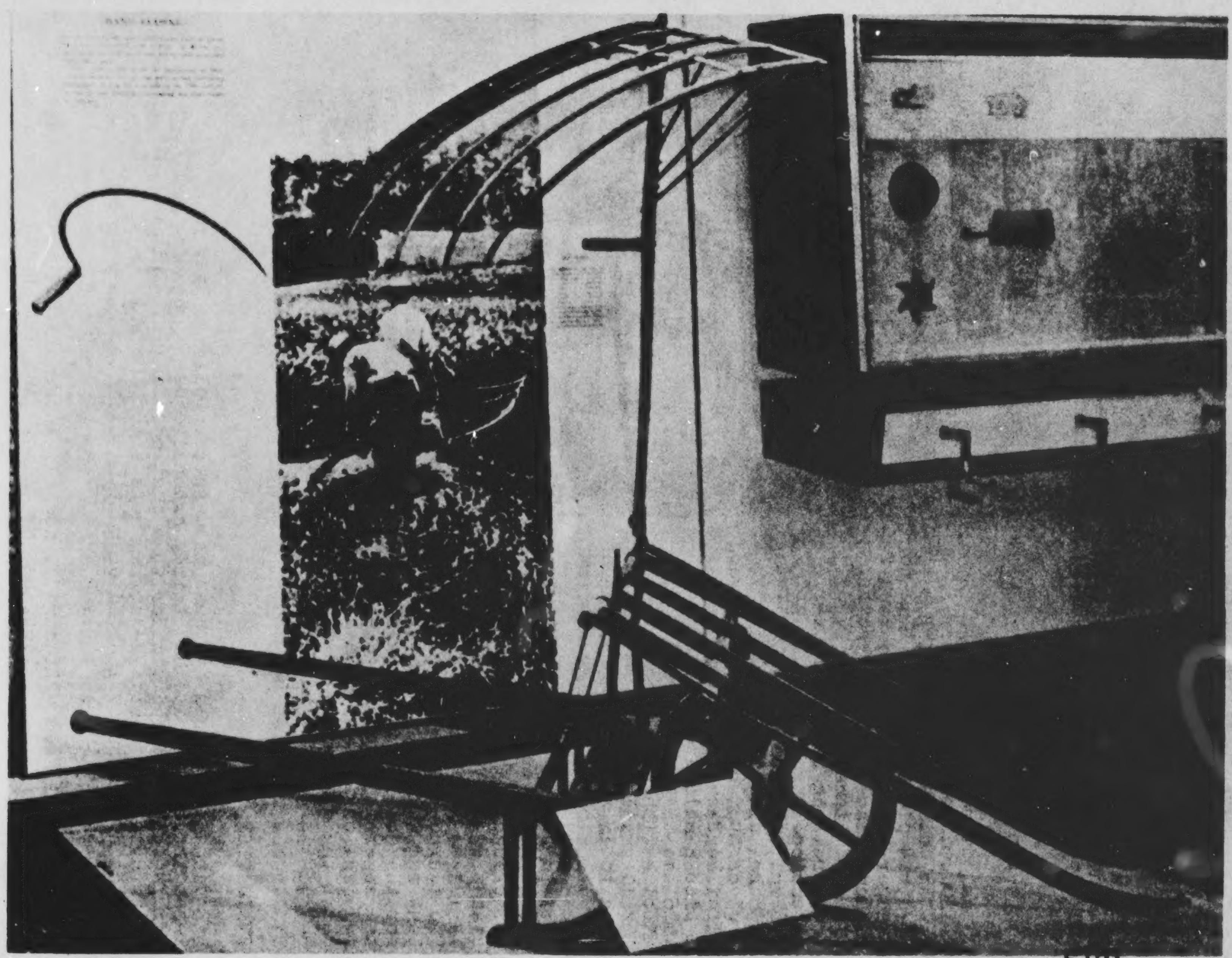

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WELL DRILLING AUGER, EXTENSIONS, AND HANDLE

ABSTRACT

This auger is fashioned from standard weight steel pipe, and is intended for use in hand drilling small diameter wells. The handle and extenions allow boring deep holes.

TOOLS AND MATERIALS

10 cm. diameter pipe (4"), 120 cm. long, for auger
3.4 cm. diameter pipe (1") 3 or 4 pieces, 30 cm. long for auger and extension socket
2.6 cm. diameter pipe (3/4") 3 or 4 pieces 6.1 or 6.4 meters long for drill extensions
1.8 cm. diameter pipe (1/2") 3 or 4 pieces 6 cm. long
2 pieces 4 x 8 x 50 cm. hardwood for handle
2 pieces mild steel 0.3 x 8 x 15 cm.
4 bolts with nuts 1 cm. diameter x 10 cm. long
Hand tools and welding equipment

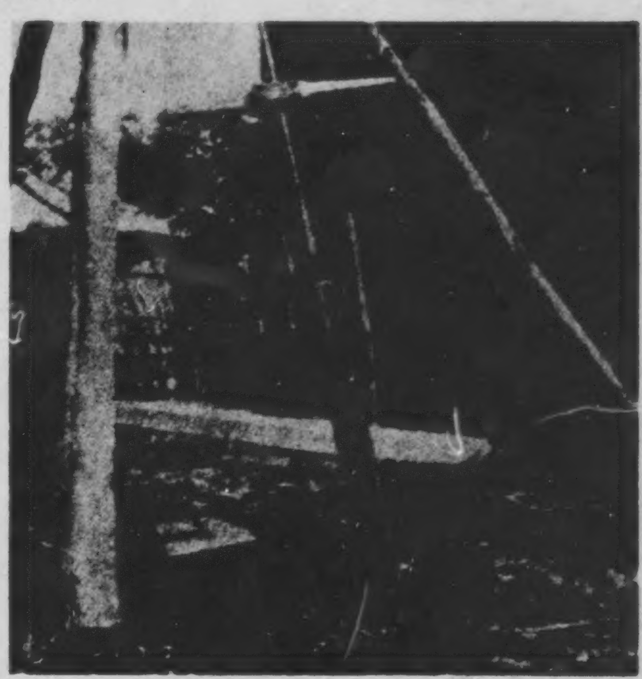


Figure 1

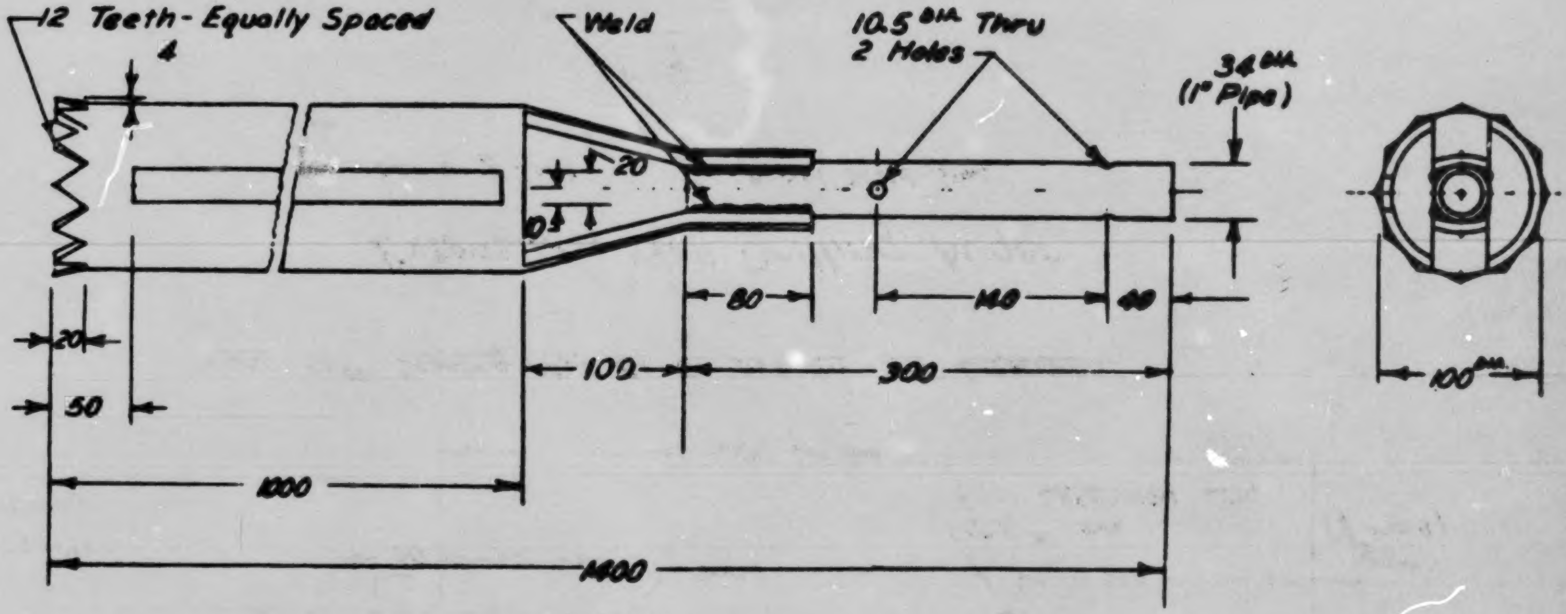
DETAILS

The auger is hacksawed out of standard weight pipe approximately 10 cm. in diameter. Lightweight tubing does not stand up in use. The flared toothed cutting edge is cut on one end. The other is cut, bent and welded to a section of 1" pipe. This pipe forms a socket for the drill line extensions. A slot running nearly the length of the auger is used when cleaning out the earth. Bends are stronger and made easier and more accurately with the metal hot. Figure 2 shows the dimensions of the auger. Figure 3 shows the extensions, while Figure 4 the handle.

EVALUATION

Equipment designed has been used successfully in Viet Nam. At least three sets have had fairly extensive use. The original auger had two cutting lips similar to a post hole auger. This was discarded in favor of the design described here since the soil in Viet Nam plugged up the auger instead of cutting cleanly. In some soils an auger with cutting lips might work more effectively.

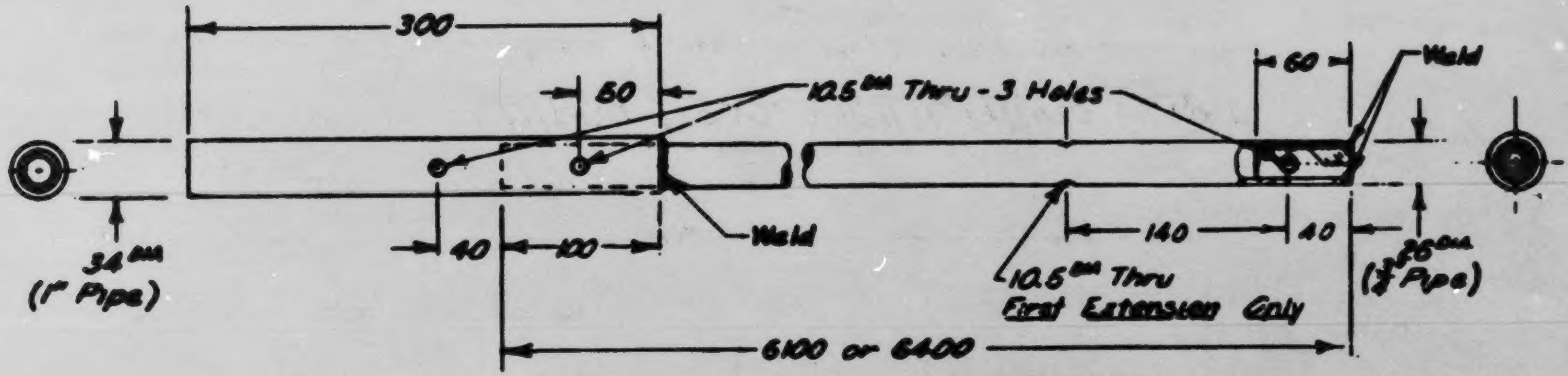
Material From - Richard G. Koegel, International Voluntary Services, Ban Me Thuot, Viet Nam, April 1959.


12 Teeth - Equally Spaced
4
Weld
10.5 DIA. Thru
2 Holes
34 DIA.
(1" Pipe)
20
10.5
80
140
40
20
50
100
300
1000
1400
100 DIA.

Cutting Head, Well Drilling Auger

Scale: $\frac{1}{2}$ Size Mat'l.: Mild Steel

Fig. 2

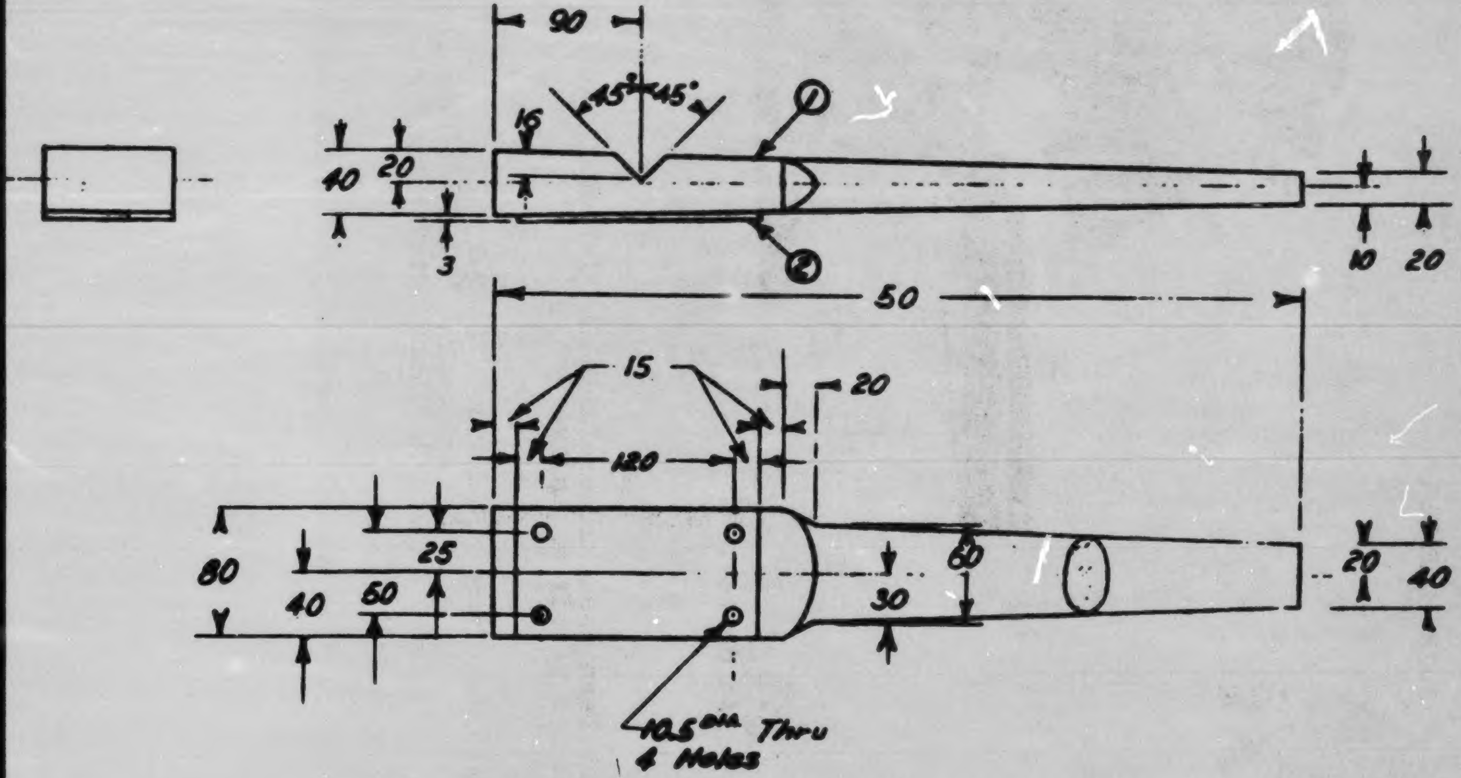

300
50
10.5 DIA Thru - 3 Holes
60
Weld
Weld
34 DIA
(1" Pipe)
40
100
140
40
26 DIA
(3/4" Pipe)
10.5 DIA Thru
First Extension Only
6100 or 6400

Note: 34 DIA Coupling May Be Omitted On Last Extension

Extension, Well Drilling Auger

Scale: 1/2 Size Mat'l: Mild Steel

Fig. 3


90
45°
45°
16
①
40
20
3
②
10
20
50
15
20
120
80
25
40
50
60
30
20
40
10.5 dia Thru
4 Holes

Note: 2 Req'd per set

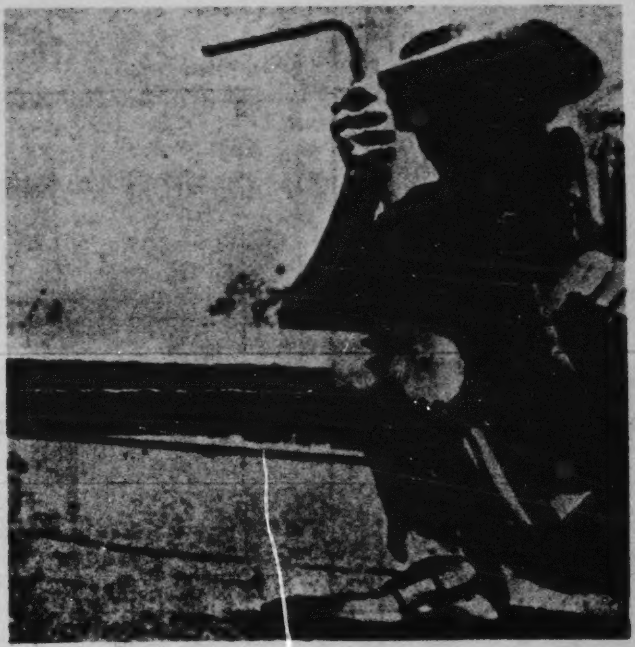
Handle, Well Drilling Auger

Scale: ½ Size Mat'l: ① Hardwood

② Mild Steel

Fig. 4

AUGER CLEANER



ABSTRACT

This simple cleaning tool allows rapid removal of soil from the well drilling auger.

TOOLS AND MATERIALS

10 cm. square of mild steel 3 mm. thick
52 cm. of steel rod, 1 cm. diameter
Welding equipment
Hacksaw
File

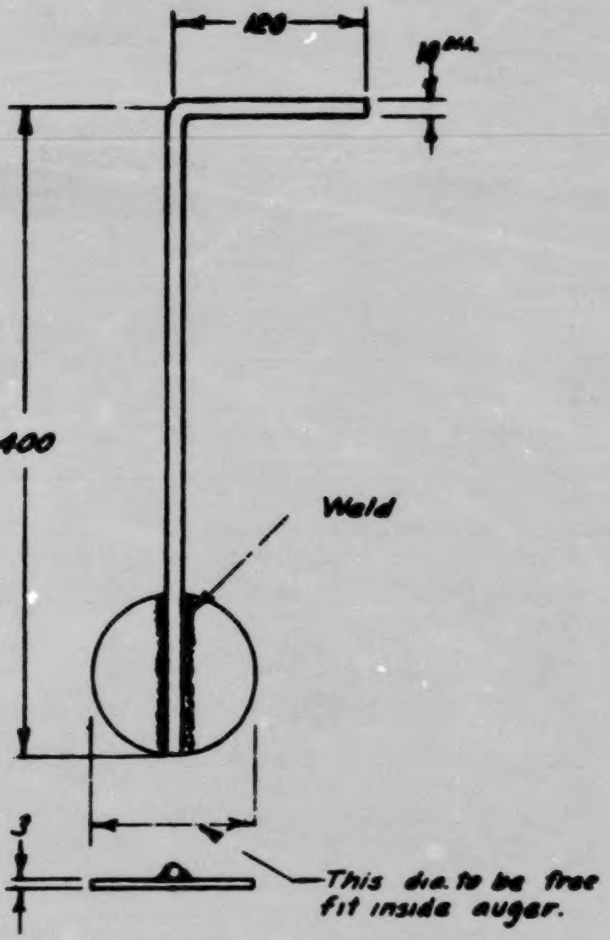
DETAILS

See Figures 1 and 2, and the entry "Well Drilling" for details of how to use this device.

EVALUATION

Equipment designed has been used successfully in Viet Nam. At least three sets have had fairly extensive use.

Material From - Richard G. Koegel
International Voluntary Services
Ban Me Thuot, Viet Nam, April 1959.


120
10 dia.
400
Weld
3
—This dia. to be free fit inside auger.

Auger Cleaner

Scale: $\frac{1}{4}$ Size Mat'l.: Mild Steel

Fig. 2

DEMOUNTABLE REAMER

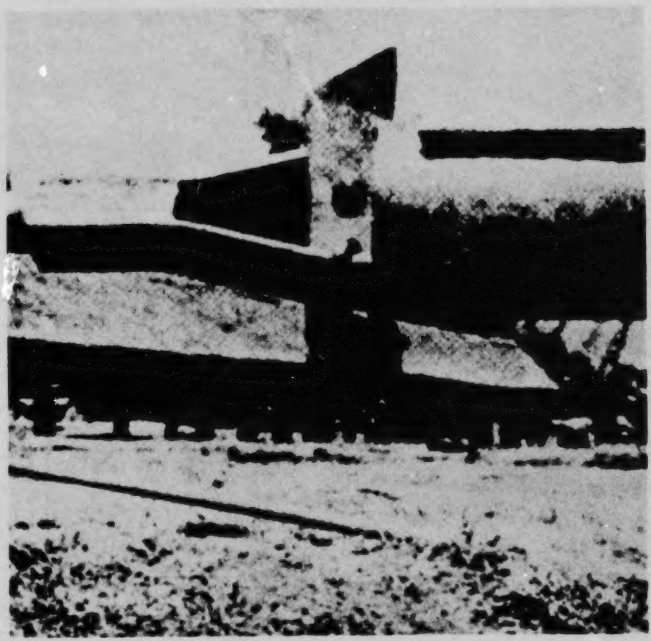


Figure 1

ABSTRACT

This reamer attaches to the Well Drilling Auger if it is desired for any reason to enlarge the diameter of the hole drilled.

TOOLS AND MATERIALS

20 cm. x 5 cm. x 6 mm. mild steel (provided the desired well diameter is 19 cm.)
Two 8 mm. diameter bolts, 10 cm. long
Hacksaw
Drill
File
Hammer
Vise

DETAILS

This reamer is mounted with two hook bolts to the top of the auger. It is made from a piece of steel 1 cm. larger than the desired well diameter. See Figure 2.

If it is desired to ream out the hole to a larger diameter, the reaming cutter is attached to the top of the auger with the two hook bolts and the bottom of the auger is plugged with a piece of wood or some mud, so that the cuttings will be caught inside the auger. For reaming, the auger is rotated with only slight down pressure. It should be emptied before it is too full in order to avoid too many cuttings falling to the bottom of the well when the auger is pulled up.

EVALUATION

The depth of a well is much more important in determining the flow than the diameter, and doubling the diameter means removing four times the amount of earth. Therefore, only under special circumstances should larger diameter wells be considered.

Material From - Richard G. Koegel
International Voluntary Services
Ban Me Thuot, Viet Nam, April 1959.

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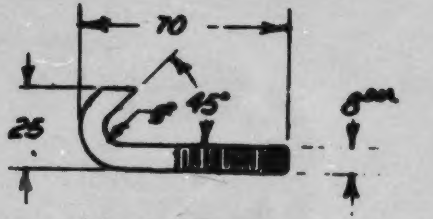
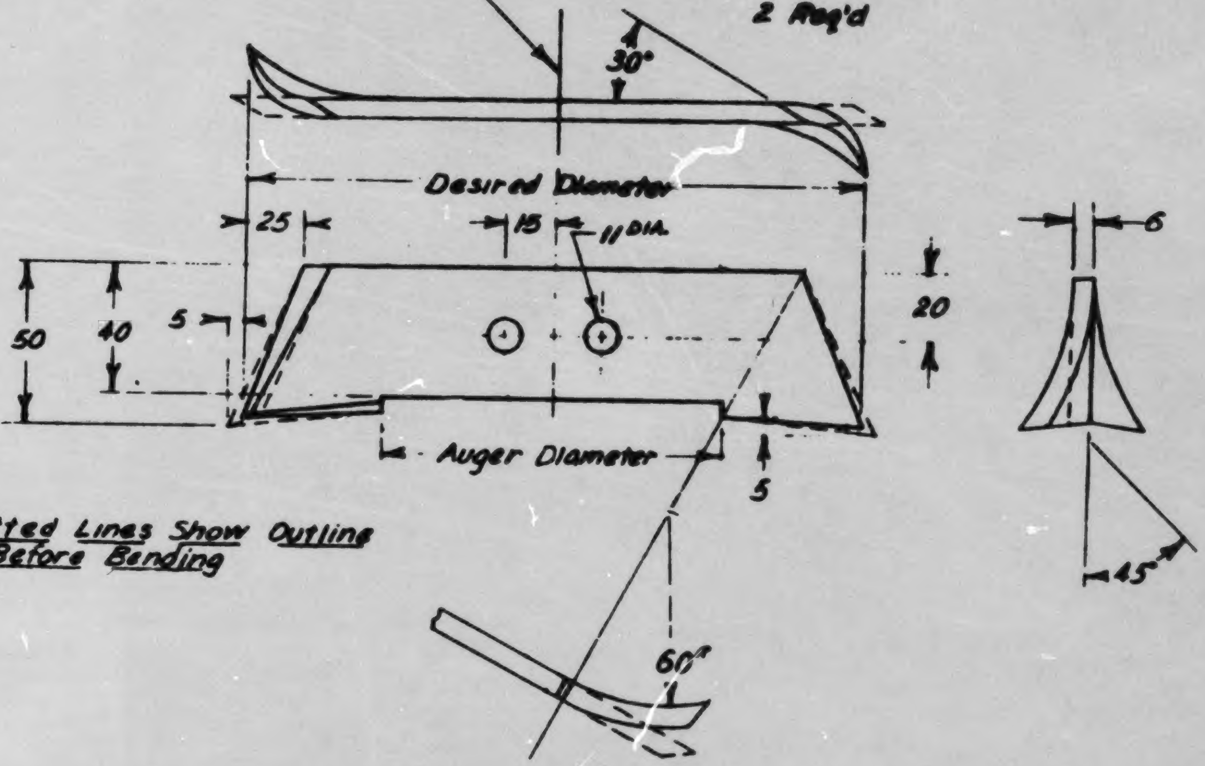

70
45°
8
25
8mm

Hook Bolt

2 Req'd


Symmetry about ℄
30°
Desired Diameter
25
15
11 DIA.
6
20
5
50
40
Auger Diameter
5
45°
60°

Note: Dotted Lines Show Outline of Piece Before Bending

Reamer, Well Drilling Auger

Scale: ½ Size Mat'l.: Mild Steel

Fig. 2

DRILLING ROCK

ABSTRACT

This heavy drilling bit has enabled hand drilling through sedimentary stone layers.

TOOLS AND MATERIALS

Steel bar about 7 cm. in diameter, about 1 1/2 m. long, weighing about 80 kilograms.
Stellite (A very hard variety of tool steel) insert for cutting edge
Anvil and Hammers for shaping
2 1/2 cm. x 2 cm. x 50 cm. steel for bail
Welding equipment

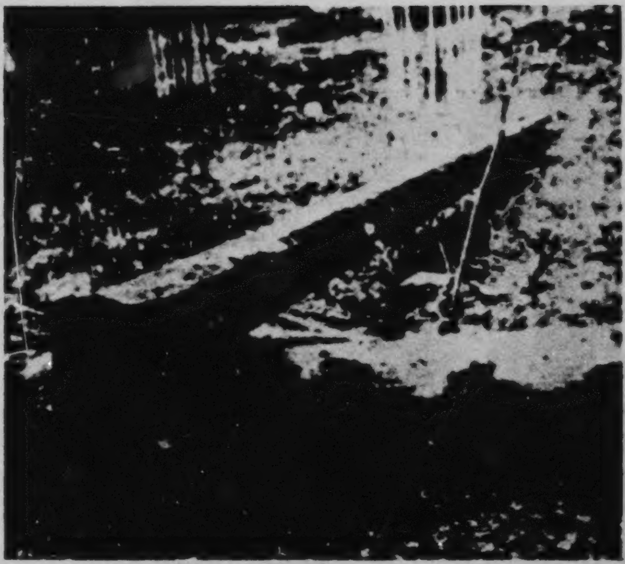


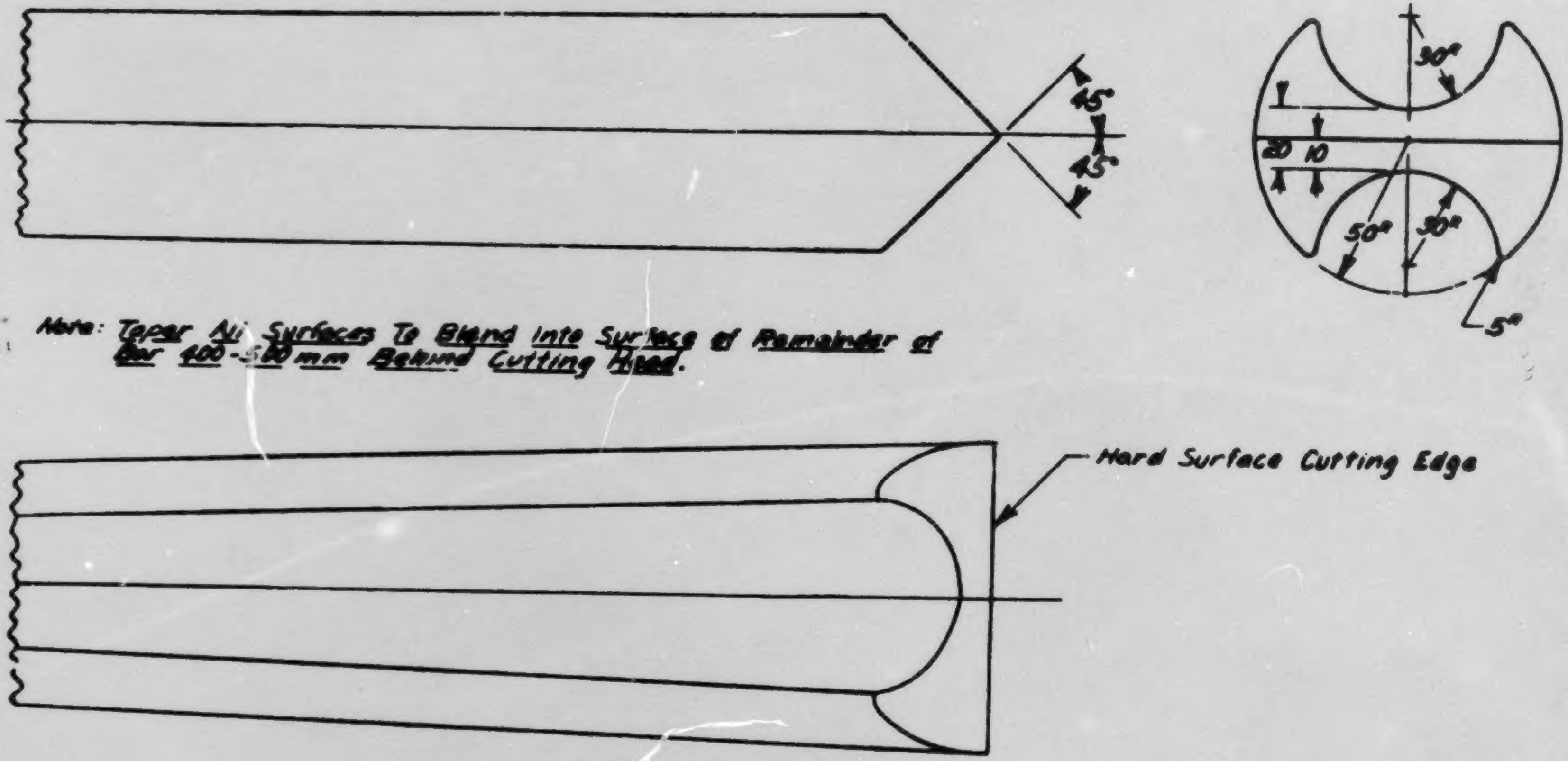
Figure 1

DETAILS

The drill bit for cutting through stone and hard formations was made from a mild steel bar weighing about 80 kilograms (175 pounds). The 90° cutting edge was hard surfaced with stellite and a bail was welded to the top for attaching a rope. The bail should be made large enough to facilitate "fishing" if the rope should ever break. See Figure 1 and 2. Originally a 1" rope was used. However, this was subject to considerable wear when working in mud and water, so recently a 1 cm. steel cable was substituted which thus far seems to be working out well. It is still too soon, though, to tell which is most suitable. A swivel is mounted between the bit and the rope or cable to allow the bit freedom to turn.

Since in some cases, a bar this size may be difficult to find or prohibitively expensive, it probably would be possible to fabricate a bit by welding a short steel cutting end on to a piece of pipe which was filled with concrete to give it the desired weight. This, however, has not yet been tried.

When stone or other substances which cannot be penetrated by the auger are encountered, the drilling bit must be used. The pulley is put in place as with the bailing bucket, and the bit is attached to its rope or cable and lowered into the well. Since the bit is heavy, a practice should be made of wrapping the rope once or twice around the back leg of the tripod, so that the bit cannot "get away" from the workers with the chance of someone being hurt or the equipment getting damaged. It was found that the easiest way to raise and drop the bit was to run the rope through the pulley and then straight back to a tree or post where it is attached at shoulder height or slightly lower. The workers then line up along the rope and raise the bit by pressing down on the rope and then drop it by quickly allowing the rope to return to its original position (Figure 3). This requires five to seven men, and in the villages occasionally more were used.


45°
45°
30°
20
10
50°
30°
5°
Hard Surface Cutting Edge

Note: Taper All Surfaces To Blend Into Surface of Remainder of Bar 400-500 mm Behind Cutting Head.

"Dimensions shown in millimeters."

Drill Bit Cutting Edge

Scale: ½ Size   Matl: Mild Steel

Fig. 2

WELL DRILLING TRIPOD AND PULLEY

ABSTRACT

This tripod is a necessary part of the equipment for drilling and supporting drill line.

TOOLS AND MATERIALS

3 poles, 15 cm. diameter, 4.25 m. long
Wood 1.1 m. x 12 cm. square, for cross bar
Pulley wheel - wood 25 cm. diameter 5 cm. thick, 5 cm. piece of 1/2" pipe
Axle bolt - fits close inside 1/2" pipe
80 cm. angle iron, 50 cm. webbs, 5 mm. thick
4 - 12 mm. bolts, 14 cm. long, nuts and washers
1 - 16 mm. bolt, 40 cm. long, nuts and washers
2 - 16 mm. bolts, 25 cm. long, nuts and washers

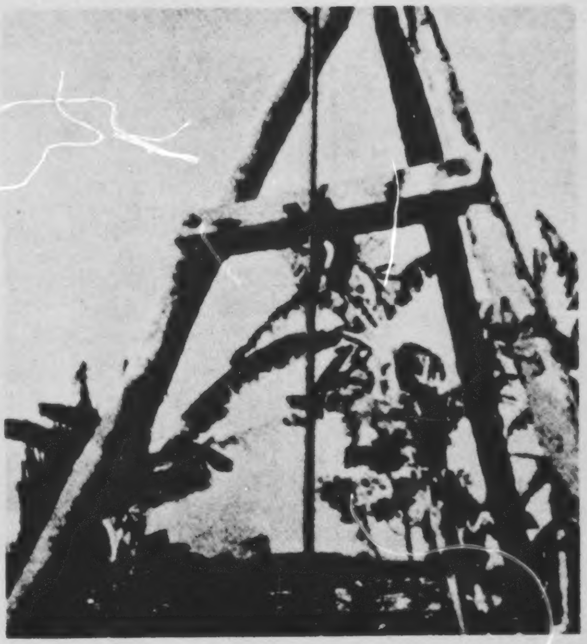


FIGURE 1

DETAILS

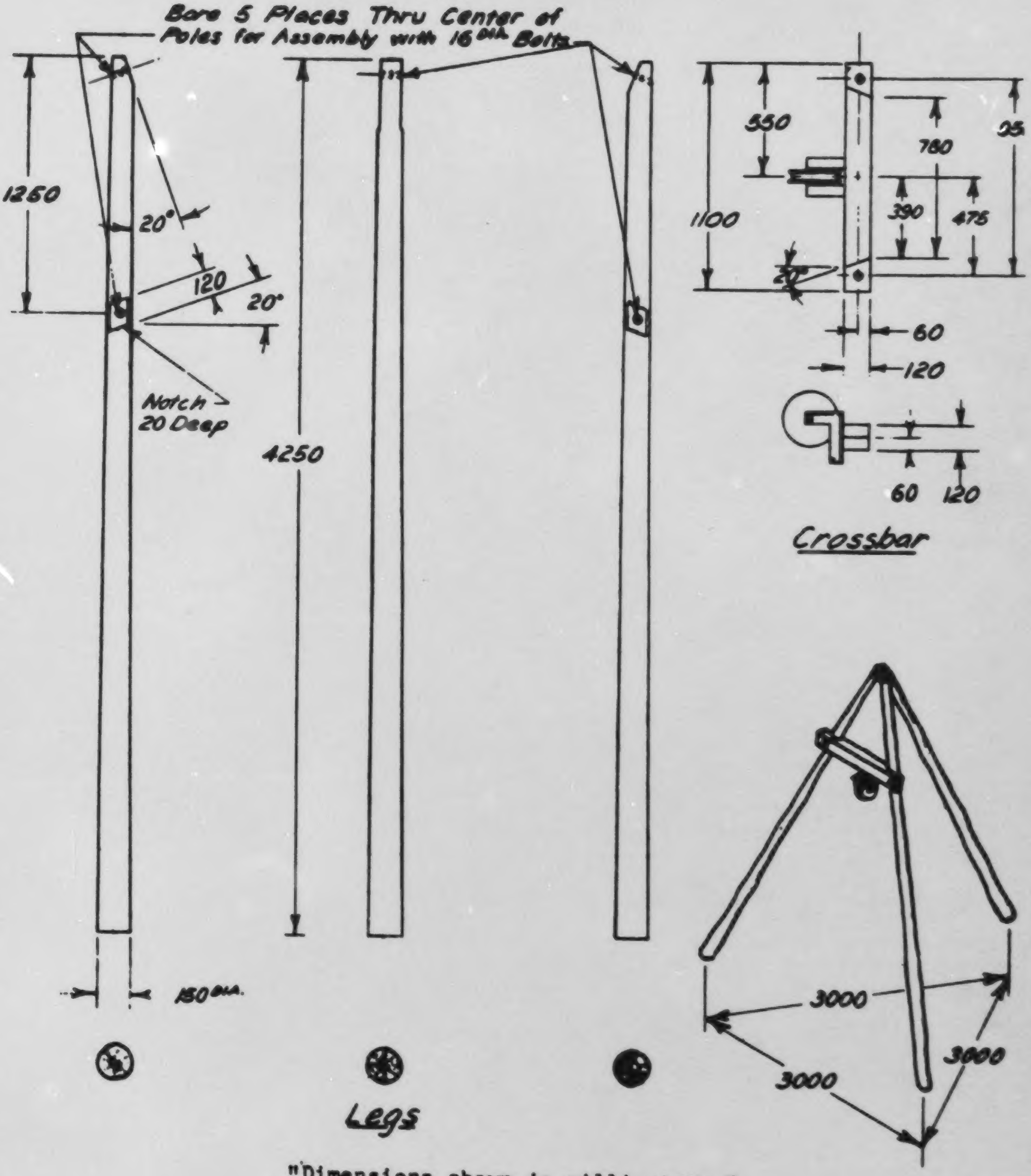
The tripod (Figure 1 and 2) which is made of poles and assembled with 16 mm. bolts serves three purposes: (1) to steady the extension of the auger when it is extending far above ground. (2) To provide a mounting for the pulley (Figure 3 and 5) used in connection with the drill bit and bailing bucket and (3) to provide a tall place for leaning long pieces of casing, pipe for pumps, or auger extensions while they are being put into or taken out of the well.

When a pin or bolt is put through the holes in the two ends of the "L" shaped pulley bracket (Figure 1 and 4) which extend horizontally beyond the front of the tripod crossbar a loose guide for the upper part of the auger extension is formed.

EVALUATION

Equipment designed has been used successfully in Viet Nam. At least three sets have had fairly extensive use.

Material From - Richard G. Koegel
International Voluntary Services
Ban Me Thuot, Viet Nam, April, 1959.


Bore 5 Places Thru Center of Poles for Assembly with 16 DIA. Bolts
1250
20°
120
20°
Notch 20 Deep
4250
150 DIA.
Legs
550
780
1100
390
475
05
20°
60
120
60
120
Crossbar
3000
3000
3000

"Dimensions shown in millimeters."

Tripod

Fig. 2

BAILING BUCKET

ABSTRACT

This device allows drilling to continue when cuttings are too loose (Figure 1) to be removed with the auger.

TOOLS AND MATERIALS

Pipe - 1 to 2 cm. smaller in diameter than the auger - say 8.5 cm. diameter; 180 cm. long
10 cm. diameter steel rod, 25 cm. long (for Bail)
Steel plate, 10 cm. square, 4 mm. thick
Steel bar, 10 cm. long, 5 mm. thick 1 cm. wide
Machine screw, nut, washer - 3 mm. diameter, 16 mm. long
Truck innertube, 4 mm. thick, 10 mm. square
Welding equipment
Drill, hacksaw, hammer vise, file

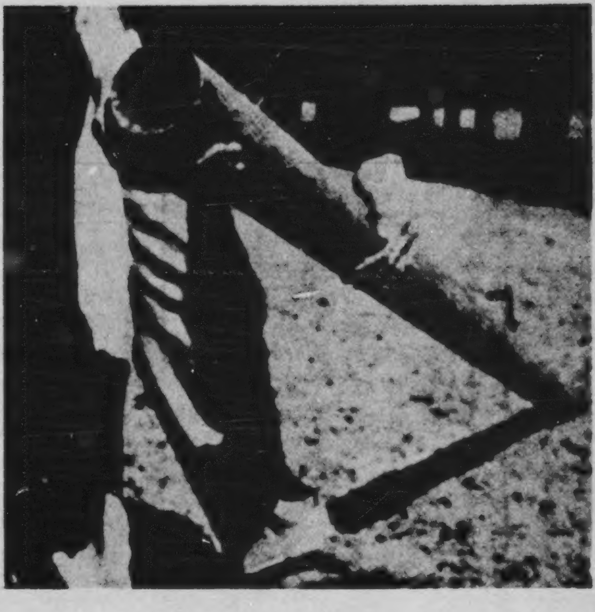


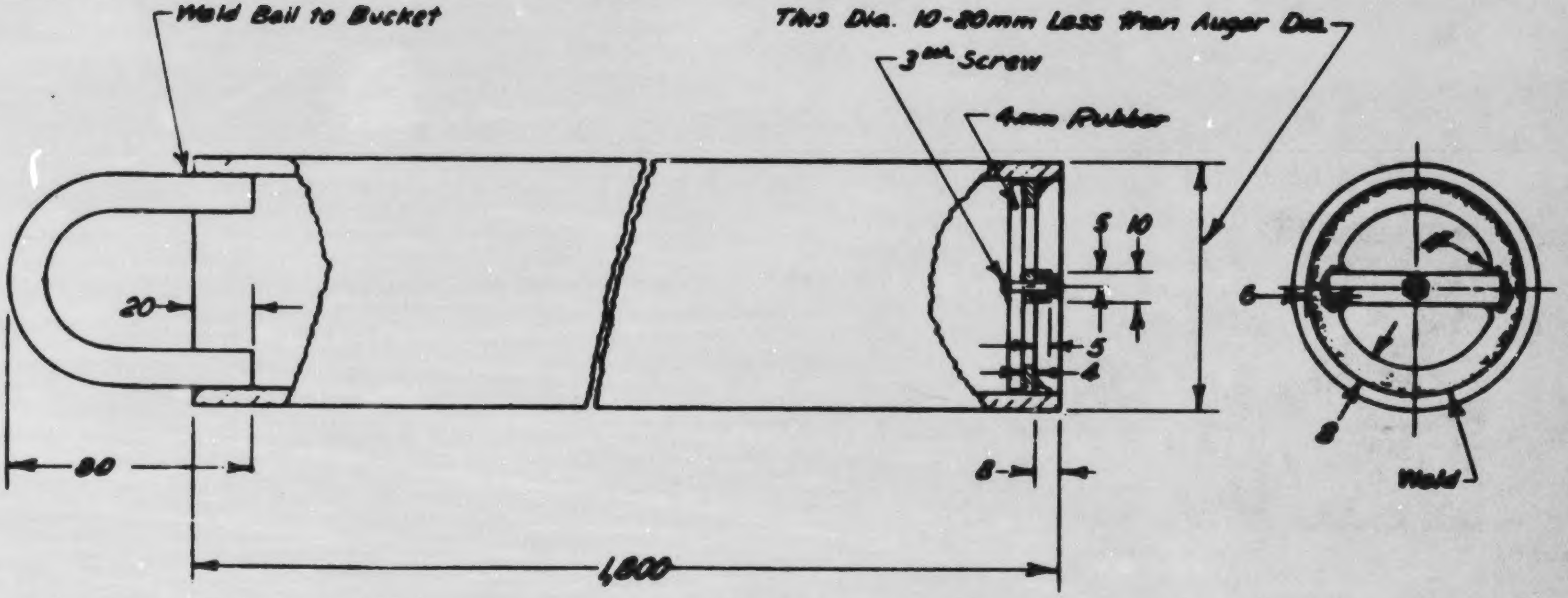
FIGURE 1

DETAILS

Both standard weight pipe and thin-walled tubing were tried for the bailing bucket. The former, being heavier, was harder to use, but did a better job and stood up better under use. Both the steel bottom of the bucket and the rubber valve should be made heavy enough since they receive hard usage. In addition, as seen in Figure 1 and Figure 2 the metal bottom is re-inforced with a crosspiece welded in place.

When water is reached, the cuttings are no longer firm enough to be brought up in the auger, and the bailing bucket must be used for cleaning out the well as work progresses. For using the bailing bucket the pulley is mounted in the pulley bracket with a 16 mm. bolt as axle. The rope which is attached to the bailing bucket can then be run over the pulley and the bucket lowered into the well. It should be noted that the pulley bracket is so designed that the rope coming off the pulley lines up vertically with the well, so that there is no need to shift the tripod.

The bucket is lowered into the well by preferably two men and allowed to drop the last meter or meter and one-half so that it will hit the bottom with a little velocity and some of the solids at the bottom of the well will be forced up into the bucket by the impact. The bucket should be then repeatedly raised and dropped one to two meters to pick up additional material. Experience will best indicate how long this should be continued for maximum results before raising and emptying the bucket.


Weld Bail to Bucket
This Dia. 10-20mm Less than Auger Dia.
3mm Screw
4mm Rubber
20
80
1,800
5
10
5
4
8
6
8
Weld

"Dimensions shown in millimeters."

Bailing Bucket

Scale: ½ Size Mat'l: Mild Steel

Fig. 2

WELL CASING AND PLATFORMS

ABSTRACT

Although plastic casing appears an ideal material, it was unavailable necessitating the development of galvanized iron and concrete casings described here.

TOOLS AND MATERIALS

230 cm. wooden V block
2 sections steel angle iron 230 cm. long
10 cm. diameter pipe, 230 cm. long
Clamps
Wooden mallet
Soldering equipment

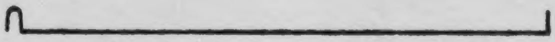
DETAILS

In home or village wells, casing usually serves two purposes: (1) to prevent any caving in of the well sides and (2) as a seal to prevent entrance of any polluted surface water into the well. Four suggestions in regard to casing are offered, the first two of which have been used successfully in connection with this project. It is proposed that the remaining two be tried, but as yet time has not permitted.

Plastic Casing - Black plastic pipe of the type used for sewers and drains proved to be almost ideal. Its friction joints could be quickly slipped together and sealed with a chemical solvent; it was light enough to be lowered into the well by hand, it could be easily sawed or drilled by hand to make a screen; and from all appearances, it was extremely durable.

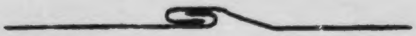
Galvanized Sheet Metal Casing - Since galvanized sheet metal was readily available in the Banmethuot area, it was decided to make sheet metal casing similar to down-spouting. The thickness of the material was 0.4 mm. (.016 inch) but a somewhat thicker gauge would have been preferable had it been available. Since the sheet metal itself would not last indefinitely, the well hole was made oversize and the annular space around the casing was poured full of a thin concrete mixture which when it hardened formed a cast concrete casing and seal outside of the sheet metal.

The metal was purchased in sheets of one meter by two meters and split into three equal pieces lengthwise which yielded three, two meter lengths of 10 cm. diameter pipe. The edges of the strips were first formed in preparation for making the seam. Since no sheet metal brake was available, this was accomplished by clamping the edges between two angle irons slightly longer than two meters and pounding the edge over with a wooden mallet. The resulting strip when seen from the end would appear as follows:



The seam is made slightly wider at one end than at the other, so that the resulting pipe has a slight taper allowing successive lengths to be slipped a short distance inside one another.

This strip was rolled up by bridging it over a two meter long wooden V block and applying pressure from above with a length of two inch pipe (Figure 1). The sheet metal strip was shifted from side to side over the V block as bending continued to get as uniform a surface as possible. When the strip had been bent enough the two edges were hooked together and the two-inch pipe was slipped inside. The ends of the two-inch pipe were then set up on wooden blocks so that it formed an anvil, and the seam was firmly crimped over as shown.



After the seam was finished any irregularities in the pipe were removed by applying pressure by hand and by use of the wooden mallet and pipe anvil. A local tinsmith and his helper were able to make six to eight lengths (12-16 meters) of the pipe per day. Three lengths of pipe were slipped together and soldered as they were made, and the remaining joints had to be soldered as the casing was lowered into the well. The lower end of the pipe was perforated with a hand drill to form a screen. After the casing was lowered to the bottom of the well, fine gravel was packed around the perforated portion of the casing to above the water level.

The cement grouting which was used around the casings varied from pure cement to a 1:1 1/2 cement : sand ratio mixed with water to a very plastic consistency. The grout was put around the casing by gravity and a strip of bamboo about ten meters long was used to "rod" the grout into place. A comparison of volume around the casing and volume of grouting used indicated that there may have been some voids left probably below the reach of the bamboo rod. These are not serious however, as long as a good seal is obtained for the first eight to ten meters down from the surface. In general, the greater proportion of cementused and the greater the space around the casing, the better seemed to be the results obtained. However, insufficient experience has been obtained to reach any final conclusions. In addition, economic considerations limit both of these factors.

It should be pointed out that some care must be taken in pouring the grout. In one case where two sections of casing were not assembled perfectly straight, the casing, as a result was not centered in the well, the pressure of the grouting was not equal all the way around, and the casing collapsed. Reasonable care and pouring the grout in several stages, allowing it to set in-between, should eliminate this. The grouting, however, cannot be poured in too many stages, since a considerable amount sticks to the sides of the well each time reducing the space for successive pourings to pass through.

A proposed modification of the above method which has not yet been tried is as follows: In areas such as Ban Me Thuot, where the structure of the material through which the well is drilled is such that there is little or no danger of cave in, the casing serves only one purpose, as a sanitary seal. It is therefore proposed that the well be cased only approximately eight meters down from the ground surface. To do this the well would be drilled to the desired depth with a diameter roughly the same as that of the casing. The well would then be reamed out to a diameter five to six centimeters larger than the casing down to the depth the casing will go. A flange fitted at the bottom of the casing with an outside diameter about equal to that of the reamed hole would serve to center the casing in the hole and to support the casing on the shoulder where the reaming stopped. Grouting would then be poured as in the original method. This modification would (1) save considerable costly material, (2) allow the well to be made a smaller diameter except near the top, (3) lessen grouting difficulties, and (4) still provide adequate protection against pollution.

Concrete Tile Casing - If the well is enlarged to an adequate diameter, precast concrete tile with suitable joints could be used as casing. This would require a device for lowering the tile into the well one by one and releasing them at the bottom. Mortar would have to be used to seal the joints above the water level, the mortar being spread on each successive joint before it was lowered. Asbestos cement casing would also be a possibility where it was available with suitable joints.

No Casing - The last possibility would be to use no casing at all. It is felt that when finances or skills do not permit the well to be cased, there are certain circumstances under which an uncased well would be superior to no well at all. This is particularly true in localities where the custom is to boil or make tea out of all water before drinking it, where sanitation is greatly hampered by insufficient water supply, and where small scale hand irrigation from wells can greatly improve the diet by making gardens possible in the dry season.

The danger of pollution in an uncased well can be minimized by: (1) choosing a favorable site for the well and (2) making a platform with drain leading away from the well which eliminates all spilled water.

Such a well should be tested frequently for pollution, and if found to be unsafe, a notice to this effect should be posted conspicuously near the well.

Well Platform - In the work in the Ban Me Thuot areas, a flat square slab of concrete (1.75 meter x 1.75 meter) was used around each well. However, under village conditions, this proved toleave much to be desired. Large quantities of water were spilled, seemingly in part due to the enthusiasm of the villagers for having a plentiful water supply, and the areas around wells became quite muddy.

The conclusion was reached that the only really satisfactory platform would be a round, slightly convex one with a small gutter around the outer edge. The gutter should lead to a concreted drain which takes the water a considerable distance from the well.

If the well platform is too big and smooth, there is a great temptation on the part of the villagers to do their laundry and other washing around the well. This should be discouraged. In villages where animals run loose it is necessary to build a small fence around the well to keep out animals, especially poultry and pigs, which are very eager to get water, but have a tendency to mess up the surroundings.

EVALUATION

Wells were installed for about $16.90 of material plus labor. This does not include a pump:

COST OF WELLS

No charge for labor has been included below, since thus far the wells have been a cooperative venture by the villagers. Assuming about 20 meters (65 feet) depth:

	VN Piasters	U.S. Dollars
Depreciation on Equipment	100	1.35
Casing, sheet metal @27.5$VN/meter x 20 m.	550	7.44
Cement and Sand for Grouting.	250	3.38
Cement and Sand for Platform.	350	4.73
TOTAL - - - -	1,250$VN	$16.90

Using other forms of casing the cost would be slightly higher or lower.

Material From - Richard G. Koegel
International Voluntary Services
Ban Me Thuot, Viet Nam, 1959

TUBEWELL WITH CASING PIPE

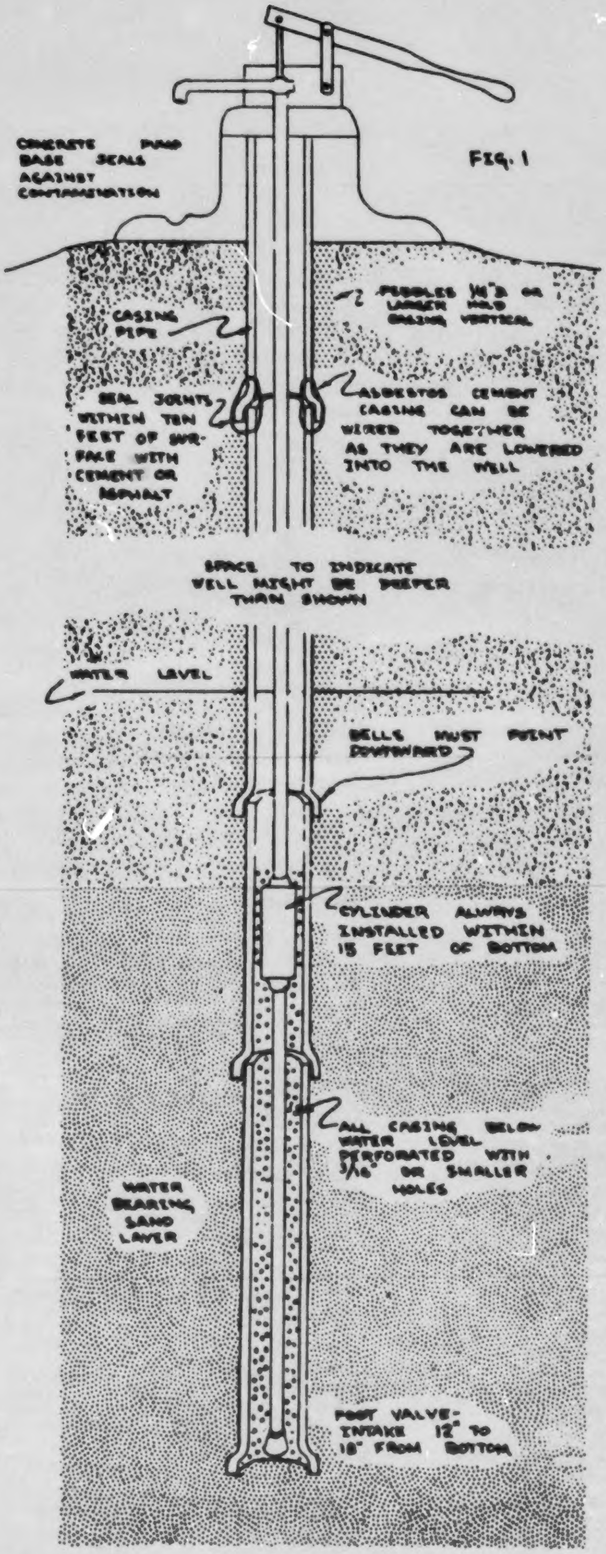


FIG. 1
CONCRETE PUMP BASE SEALS AGAINST CONTAMINATION
PEBBLES 1/4" Ø OR LARGER HOLD CASING VERTICAL
CASING PIPE
SEAL JOINTS WITHIN TEN FEET OF SURFACE WITH CEMENT OR ASPHALT
ASBESTOS CEMENT CASING CAN BE WIRED TOGETHER AS THEY ARE LOWERED INTO THE WELL
SPACE TO INDICATE WELL MIGHT BE DEEPER THAN SHOWN
WATER LEVEL
BELLS MUST POINT DOWNWARD
CYLINDER ALWAYS INSTALLED WITHIN 15 FEET OF BOTTOM
ALL CASING BELOW WATER LEVEL PERFORATED WITH 3/16" OR SMALLER HOLES
WATER BEARING SAND LAYER
FOOT VALVE-INTAKE 12" TO 18" FROM BOTTOM

ABSTRACT

Where soil conditions permit, the tubewell described here will provide pure water, is much easier to install, and costs considerably less than large diameter wells.

TOOLS AND MATERIALS

Asbestos cement, tile, concrete, or even galvanized iron will do.
Casing pipe (from pump to water-bearing layer to below minimum water table).
Sand
Gravel
Cement
Device for lowering and placing casing.
Drilling rig - see "Tubewell Boring"
Foot valve, cylinder, pipe, hand-pump.

DETAILS

In areas where a simple earth borer or earth auger works (ie. alluvial plains with few rocks in the soil), and where there is a permeable (sandy) water-bearing layer, 50 feet or less from the surface, the tubewell will probably work well.

It is a sealed well which will provide pure water and offers no hazard to small children. It is intended for the individual family or small group of families since it may not have the capacity for a large group. Since there is only a small hole to dig and a small amount of purchased material involved, the tubewell is quite inexpensive to install.

Because of the small diameter of these wells, their storage capacity is limited. Therefore, their yield will depend largely upon the rate with which water from the surrounding soil flows into the well. From a saturated sand layer the flow is rapid. Inflowing water quickly replaces the water being drawn from the well. A well tapping such a layer seldom goes dry. However, even when water-bearing sand cannot be reached, the requirements of the household may be such that a well with even a limited storage capacity can be utilized.

The hole is dug as deep as possible into the water-bearing strata as described in "Tubewell Boring." The diggings are placed near the hole to make a mound, which later will serve to drain spilled water away from the well. This is important since backwash is one of the few sources of contamination for this type of well. The entire casing pipe below water level should be perforated with many small holes. These should be no larger than 3/16" in diameter at the maximum. Holes larger than this will allow coarse sand to be washed inside. This will plug up the well. Fine particles of sand, however, are expected to enter. These should be small enough to be pumped immediately out through the pump. This keeps the well clear. It may be that the first water from the new well will bring with it large quantities of fine sand. When this happens, the first strokes should be strong and steady and continued until the water comes clear.

Perforated casing is lowered, bell end downward, into the hole using the device shown in Figure 2. When properly positioned, the trip cord is pulled and the next section prepared and lowered. Since holes are easily drilled in Asbestos cement pipe, they can be wired together at the joint and lowered into the well. Be sure the bells point downward, since this will prevent surface water or backwash from entering the well without the purifying filtration effect of the soil as well as sand and dirt from filling the well. Install the casing vertical and fill the remaining space with pebbles. This will hold the casing plumb. The casing should rise 1' to 2' above ground level and be surrounded with a concrete pedestal to hold the pump and drain spilled water away from the hole. The casing joints that are within 10 feet of the surface should be sealed with concrete or bituminous material.

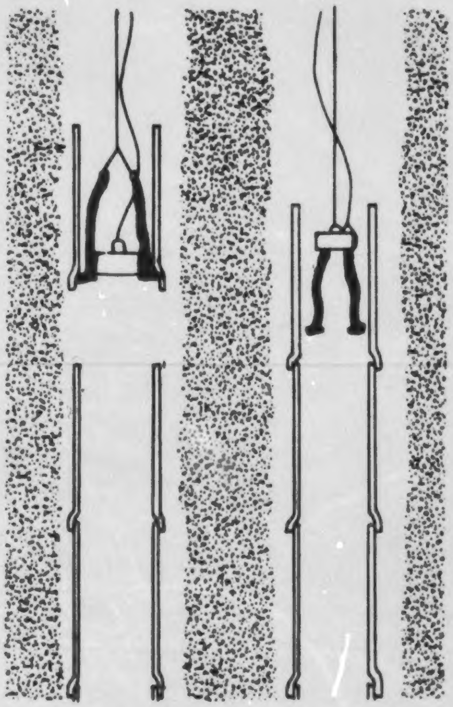


Figure 2

EVALUATION

Many of these wells were installed by the American Friends Service Committee, Barpali team, and all have been producing water for several years.

Material From - "Explanatory Notes on Tubewells"
by Wendell Mott, AFSC, Barpali
project.

TUBEWELL BORING

ABSTRACT

This simple hand drilling rig bores 6" to 8" diameter holes up to 50' deep for installation of tubewells.

TOOLS AND MATERIALS

Earth auger
Coupling to attach to 1" drill line
  (see other entries on earth augers)

Standard weight galvanized steel pipe
  Four - 10' sections of 1" diameter
    (2 pieces have threads on one end
    only; others need no threads.)
  Two - 3 1/2' sections of 1" diameter
    (1 piece has threads on one end
    only; the other needs no thread.)
      (Above sections for drill line.)

  Two - 2' sections of 1" diameter
    (both threaded one end only)
      (Sections for turning handle.)

  Four - 1' sections of 1 1/4" diameter
      (Sections for Joint A.)

  One - 9" section of 1 1/4" diameter
    (threaded one end only)
  One - 14" section of 1 1/2" diameter
    (threaded one end only)
  One - 1 1/4" to 1" reducer coupling
  One - 1 1/2" to 1" reducer coupling
      (Sections and couplings for
      Joint B.)

  One - 1" T coupling (turning handle)

  Eight - 3/8" diameter hex head steel
    machine bolts 1 3/4" long with nuts.

  Two - 3/8" diameter hex head steel
    machine bolts 2" long with nuts.

  Nine - 3/8" steel hex nuts

  One - 1/8" diameter countersink head
    iron rivet 1/2" long
  One - 1/16" sheet steel 3/8" x 1"
      (To make toggle bolt.)

  Drills - 1/8", 13/32", 13/16"

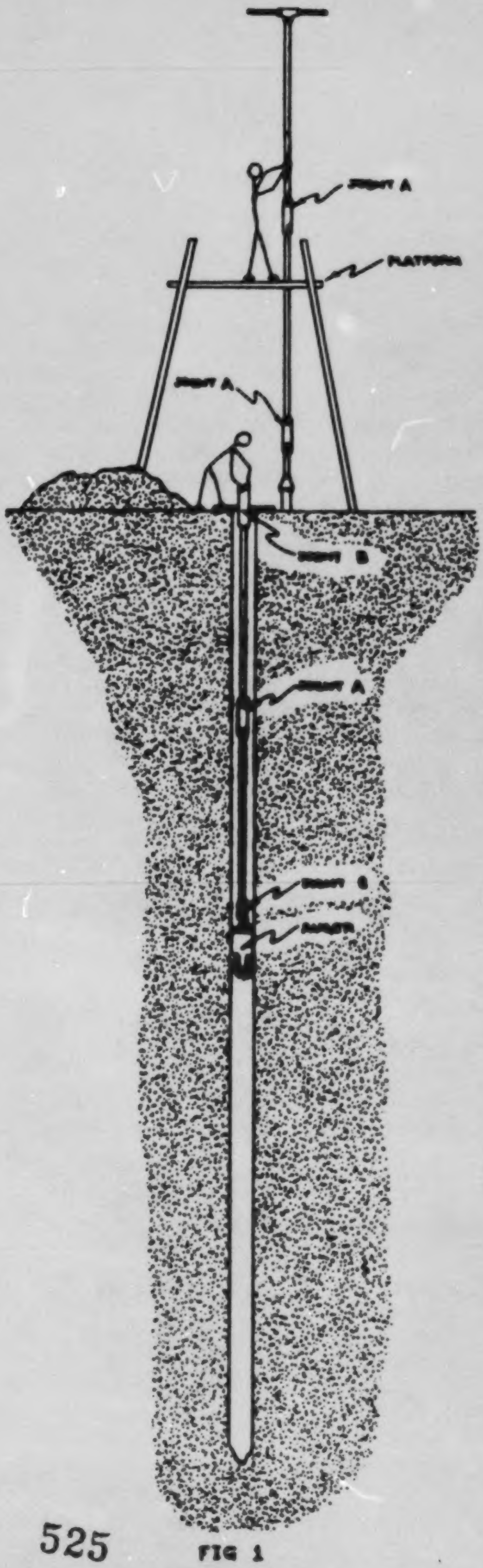


FIG 1

Countersink
Thread cutting dies or buy pipe already threaded.
Small tools - wrenches, hammer, hacksaw, files, etc.
Wood, nails, rope, ladder, etc. for platform.

DETAILS

This method will work in places where the water level is within 40 to 50 feet from the surface, and where there are no rock formations to obstruct drilling. These conditions are most often found in the alluvial plains of river valleys. See the entry on tubewells for directions to assemble the well. This description covers the tools and the method for drilling the hole.

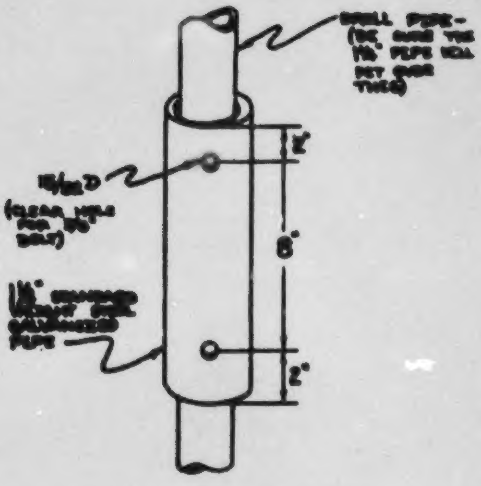


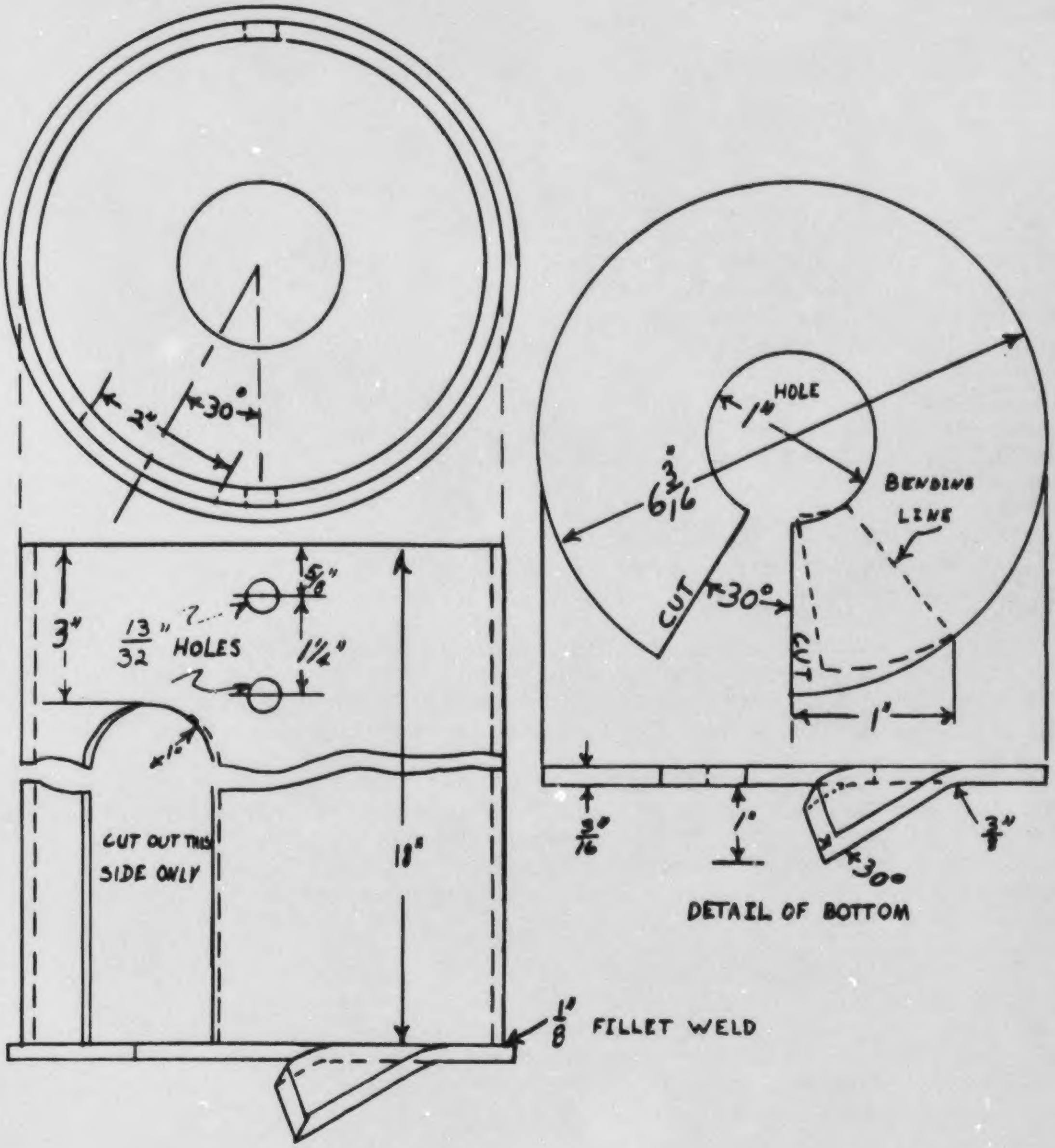
FIG 2
JOINT A

Basically the method consists of rotating an ordinary earth auger. As the auger penetrates the earth, it fills with soil. When full it is pulled out of the hole and emptied. As the hole gets deeper, more sections of drilling line are added to extend the shaft. Joint A in Figures 1 and 2 describe a simple method for attaching new sections.

By building an elevated platform 10 to 12 feet from the ground, a 25 foot long section of drill line can be balanced upright. Longer lengths are too difficult to handle. Therefore, when the hole gets deeper than 25 feet, the drill line must be taken apart each time the auger is removed for emptying. Joint B facilitates the operation. See Figure 1 and 3.

Joint C is proposed to allow rapid emptying of the auger. Some soils respond well to drilling with an auger that has two sides open. These are very easy to empty, and would not require Joint C. Find out what kinds of augers are successfully used in your area, and do a bit of experimenting to find the one best suited to your soil. See the entries on augers.

Joint A has been found to be faster to use and more durable than pipe threaded connectors. The pipe threads become damaged and dirty and are difficult to start. Heavy, expensive pipe wrenches get accidentally dropped into the well and are hard to get out. By using a sleeve pipe fastened with two 3/8" bolts, these troubles can be avoided. A small ten-cent bicycle wrench or the inexpensive bolts will not obstruct drilling if dropped in. Be sure the 1 1/4" pipe will fit over your 1" pipe drill line before purchase. See Figure 2.


2"
30°
3"
5/8"
13/32" HOLES
1 1/4"
1"
CUT OUT THIS SIDE ONLY
18"
1/8" FILLET WELD
HOLE
1"
6 3/16
BENDING LINE
CUT
30°
CUT
1"
3/16"
1"
30°
3/8"

DETAIL OF BOTTOM

FIG. 2

Four 10 foot sections and two 3 1/2 foot sections of pipe are the most convenient lengths for drilling a 50 foot well. Drill a 13/32" diameter hole through each end of all sections of drill line except those attaching to Joint B and the turning handle which must be threaded joints. The holes should be 2" from the end.

When the well is deeper than 25 feet several features facilitate the emptying of the auger as shown in Figure 3 and 4. First the full auger is pulled up until Joint B appears at the surface. See Figure 4A. Then a 3/4" diameter rod is put through the hole. This allows the whole drill line to rest on it making it impossible for the part still in the well to fall in. Next remove the toggle bolt, lift out the top section of line and balance it beside the hole. See Figure 4B. Pull up the auger, empty it, and replace the section in the hole where it will be held by the 3/4" rod. See Figure 4C. Next replace the upper section of drill line. The 3/8" bolt acts as a stop which allows the holes to be easily lined up for reinsertion of the toggle bolt. Finally withdraw the 3/4" rod and lower the auger for the next drilling. Mark the location for drilling the 13/32" diameter hole in the 1 1/4" pipe through the toggle bolt hole in the 1 1/2" pipe. If the hole is located with the 1 1/4" pipe resting on the stop bolt, the holes are bound to line up.

Sometimes a special tool is needed to penetrate a water-bearing sand layer, because the wet sand caves in as soon as the auger is removed. If this happens a perforated casing is lowered into the well, and drilling is accomplished with an auger that fits inside the casing. A percussion type with a flap, or a rotary type with solid walls and a flap are good possibilities. See the entries describing these devices. The casing will settle deeper into the sand as sand is dug from beneath it. Other sections of casing must be added as drilling proceeds. Try to penetrate the water bearing sand layer as far as possible (at least 10 feet). Ten feet of perforated casing embedded in such a sandy layer will provide a very good flow of water.

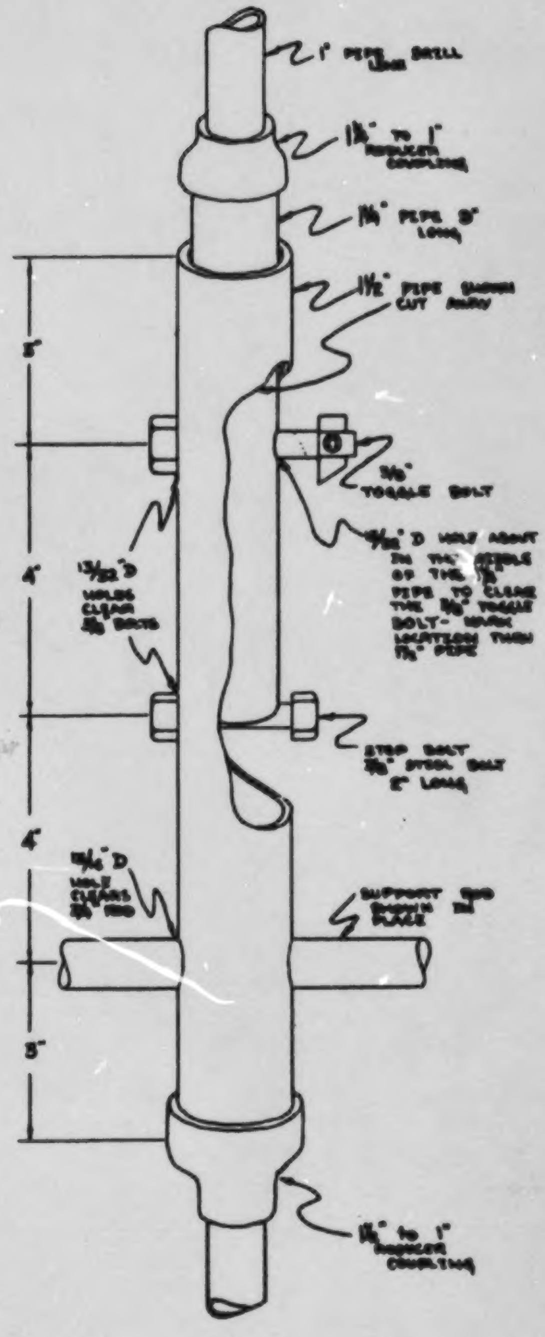

1" PIPE DRILL LINE
1¼" TO 1" REDUCER COUPLING
1¼" PIPE 3' LONG
1½" PIPE SHOWN CUT AWAY
5"
3/8" TOGGLE BOLT
13/32" D HOLE ABOUT IN THE MIDDLE OF THE 1¼" PIPE TO CLEAR THE 3/8" TOGGLE BOLT- MARK LOCATION THRU 1½" PIPE
4"
13/32" D HOLES CLEAR 3/8" BOLTS
STOP BOLT 3/8" STEEL BOLT 2" LONG
4"
13/16" D HOLE CLEARS 3/4" ROD
SUPPORT ROD SHOWN IN PLACE
5"
1¼" TO 1" REDUCER COUPLING

FIG 3
JOINT B

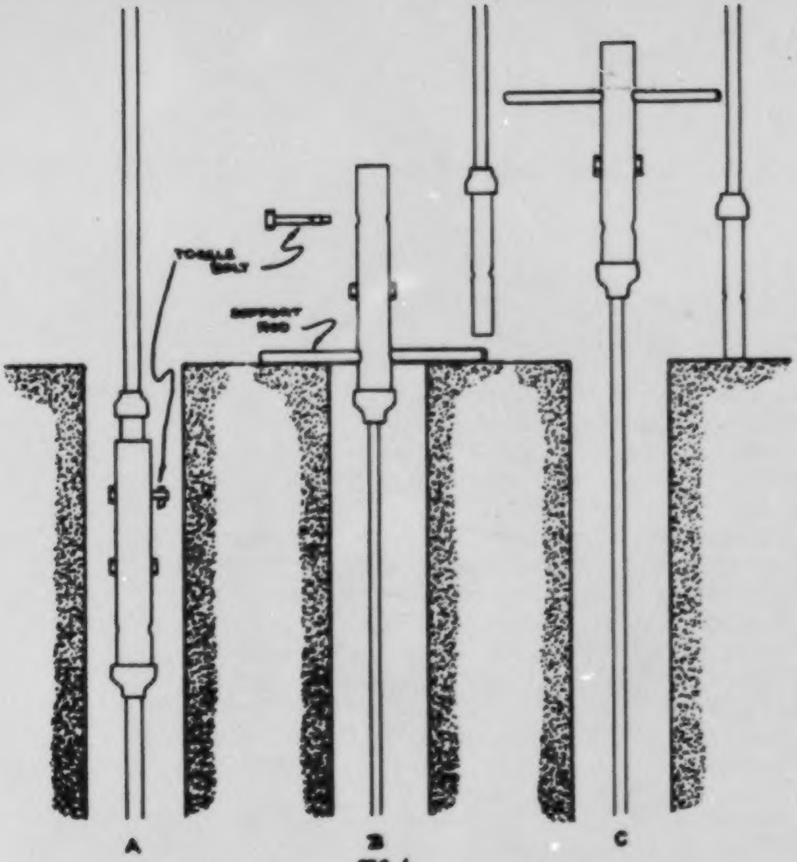


FIG 4
JOINT B IN OPERATION

EVALUATION

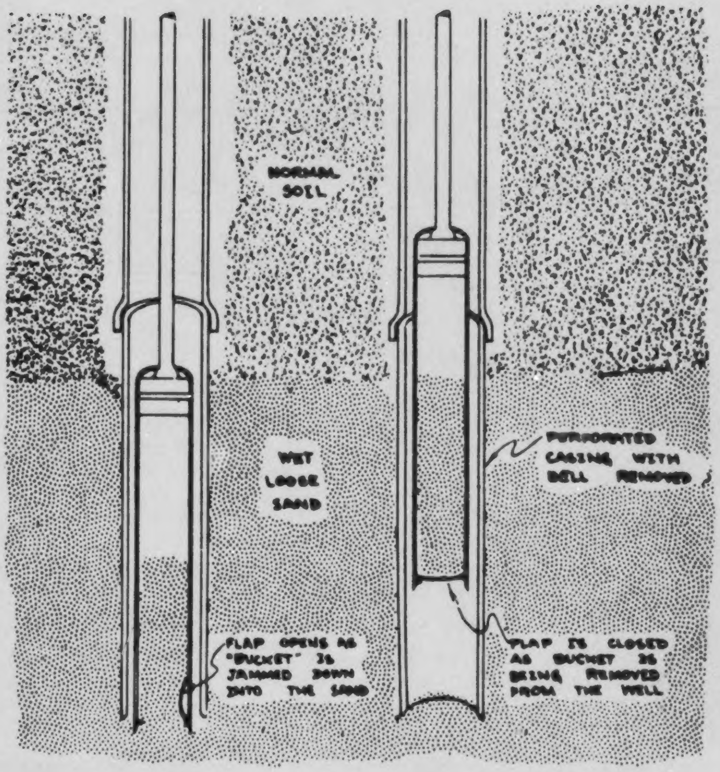
A crew of five men can dig a fifty foot well in two days. Many wells have been dug with this equipment by the American Friends Service Committee Barpali team in India.

Material From - "Explanatory Notes on Tubewells"
by Wendell Mott, AFSC, Rasulia
Friends Rural Center.

TUBEWELL SAND BAILER

ABSTRACT

When loose wet sand is encountered when boring a tubewell and the walls begin to cave, this device allows digging from inside the perforated casing.


NORMAL SOIL
WET LOOSE SAND
PERFORATED CASING WITH BELL REMOVED
FLAP OPENS AS "BUCKET" IS JAMMED DOWN INTO THE SAND
FLAP IS CLOSED AS BUCKET IS BEING REMOVED FROM THE WELL

TOOLS AND MATERIALS

5" diameter steel tube 3' long
5" square of truck innertube or leather.
Coupling from 5" to 1" pipe
small tools

DETAILS

By repeatedly jamming this "bucket" into the well, sand will be removed from in front of the perforated casing allowing it to settle deeper into the sand layer. The casing prevents the walls from caving in. The first section of casing has the bell removed; at least one other section rests on top of it to help force it down as digging proceeds. Try to penetrate the water bearing sand layer as far as possible (at least 10 feet). Ten feet of perforated casing embedded in such a sandy layer will provide a very good flow of water.

Be sure to try your sand "bucket" in wet sand before attempting to use it at the bottom of your well.

EVALUATION

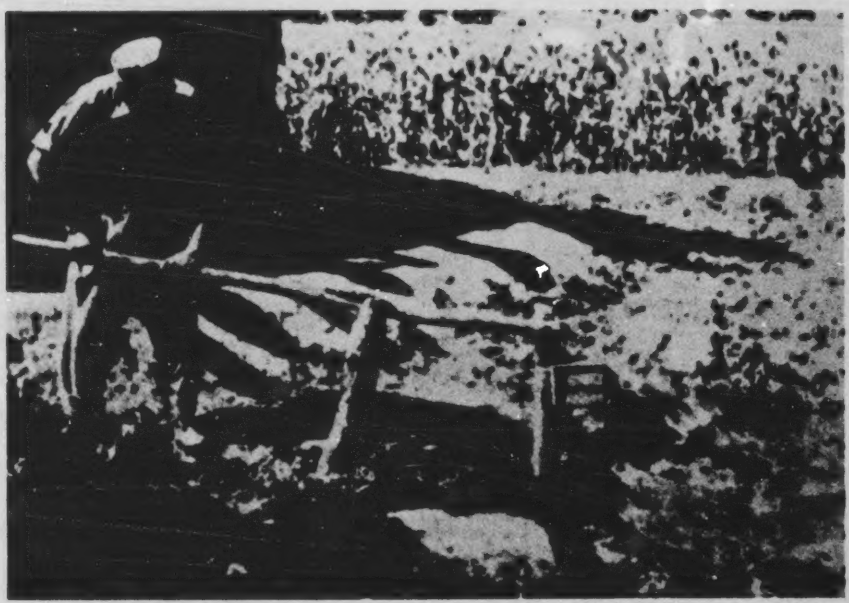
Used by the American Friends Service Committee Barpali Team in making many tubewells in India.

Material From - "Explanatory Notes on Tubewells"
by Wendell Mott, AFSC, Rasulia
Friends Rural Center.

INERTIA HAND PUMP FOR IRRIGATION

ABSTRACT

This efficient lift pump provides 30 gpm (gallons per minute) at 4 meters to 75 gpm at 1 meter. The pump is easily built by a tinsmith, and the three moving parts require almost no maintenance. It has been built in three sizes for different water levels.



TOOLS AND MATERIALS

- Soldering equipment
- Drill and bits or punch
- Hammer
- Saws
- Tinsnips
- Anvil - (Railroad rail or iron pipe)

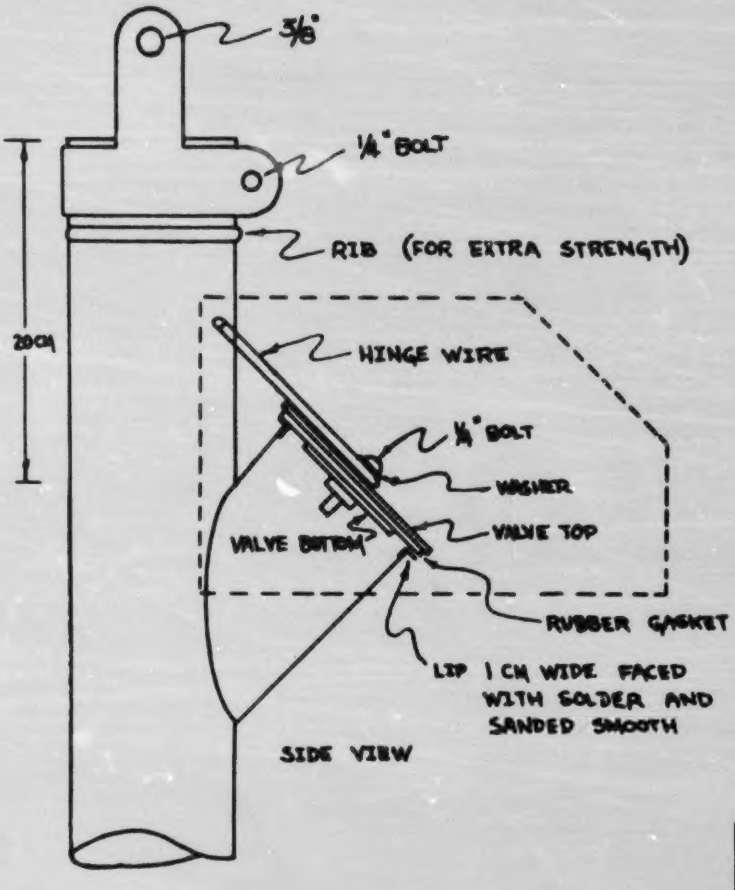
Material for 1 meter lift pump

Galvanized iron-	1 piece	61 cm x 32 cm	(shield)
	1 "	21 cm x 22 cm	(shield cover)
	1 "	140 cm x 49 cm	(pipe)
	1 "	15 cm x 15 cm	(top of pipe)
	1 "	49 cm x 30 cm	("Y" pipe)
Barrel metal-	1 piece	15 cm x 54 cm	(bracket)
	1 "	12 cm - diameter	(valve-bottom)
	1 "	18 cm - diameter	(valve-top)
Wire -	1 piece	4 mm - diameter, 32 cm long	(hinge)

DETAILS

The pump is made from galvanized sheet metal of the heaviest weight obtainable which can be easily worked by a tinsmith. The pipe is formed and made air tight by soldering all joints and seams. The valve is made from the metal of discarded barrels and a piece of truck inner tube rubber. The bracket for attaching the handle is also made from barrel metal.

There are two points to be remembered concerning this pump. One is that the distance from the top of the pipe to the top of the hole where the short section of pipe is connected must be 20 cm. The air which stays in the pipe above this junction serves as an air cushion (to prevent "hammering") and regulates the number of strokes pumped per minute. The second point is to remember to operate the

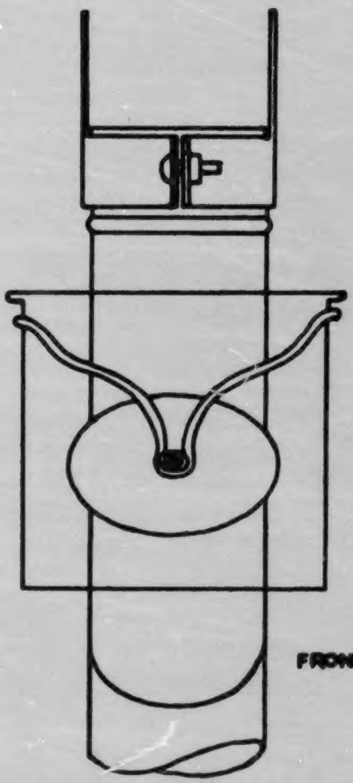

3/8"
1/4" BOLT
RIB (FOR EXTRA STRENGTH)
20CM
HINGE WIRE
1/4" BOLT
WASHER
VALVE TOP
VALVE BOTTOM
RUBBER GASKET
LIP 1 CM WIDE FACED WITH SOLDER AND SANDED SMOOTH

SIDE VIEW

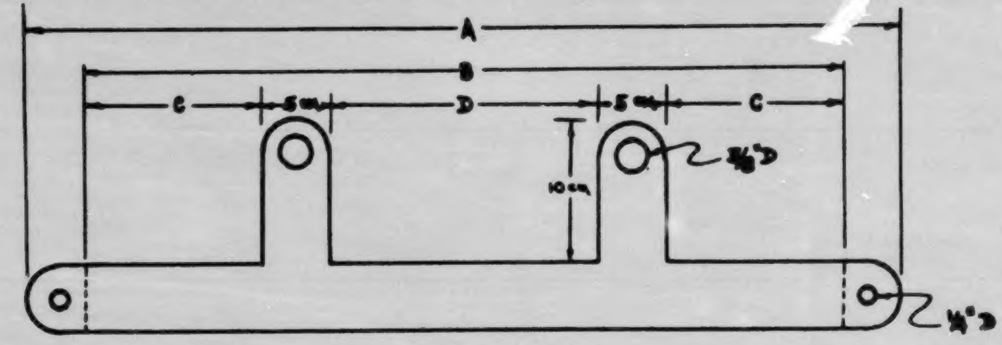
pump with short strokes (15 to 20 cm) and at a rate of about 80 strokes per minute. There is a definite speed at which the pump works best and the operator will soon get the "feel" of his particular pump.

In building the two larger size pumps it is sometimes necessary to strengthen the pipe to prevent collapsing which occurs if the pipe is allowed to hit the side of the well. Strengthening may be done by forming "ribs" about every 30 cm below the valve or banding with bands made from barrel metal and attached with 1/4" bolts.

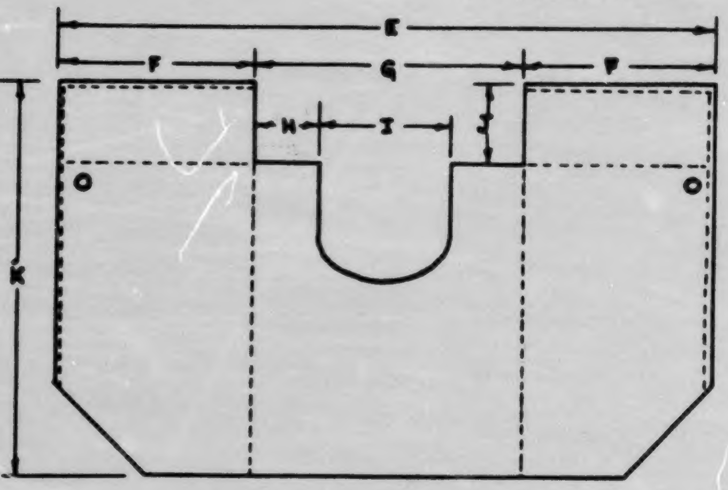
The handle is attached to the pump and post with 3/8" bolts or large nails of similar size.



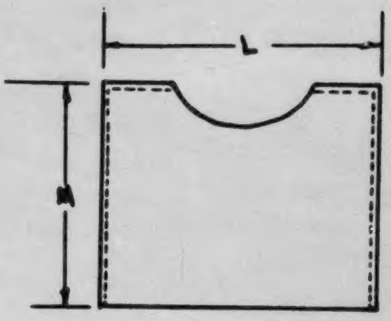
FRONT VIEW


A
B
C
5 cm
D
5 cm
C
10 cm
3/8"D
1/4"D

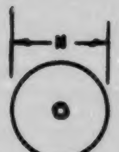
HANDLE BRACKET



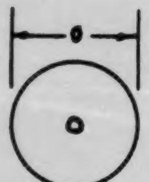
SHIELD



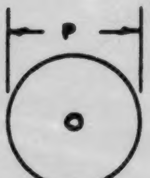
SHIELD COVER



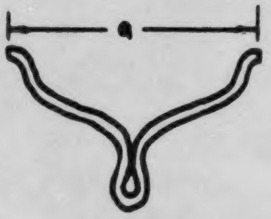
VALVE BOTTOM



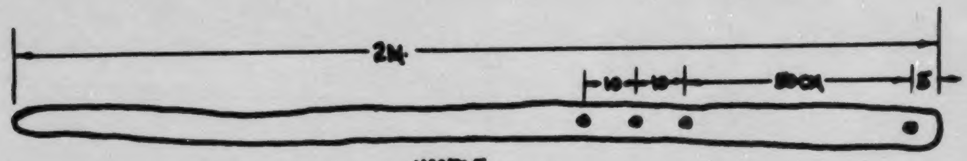
GASKET



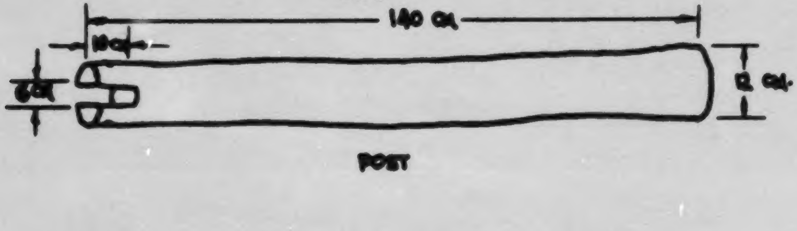
VALVE TOP



HINGE


2M.
10
10
80 CM
5

HANDLE


140 CM.
10 CM
6 CM
12 CM.

POST

DIMENSION OF PARTS ACCORDING TO PUMP SIZE

Part	Material	8 cm pipe	10 cm pipe	15 cm pipe
Handle Bracket	Barrel Metal			
A		34 cm	40 cm	54 cm
B		24	30	44
C		3½	5	8½
D		7	10	17
Shield	Galvanized tin			
E		43	49	61
F		14	16	20
G		14	16	20
H		3	3	2½
I		8	10	15
J		4	4	4
K		30	30	32
Shield Cover	Galvanized tin			
L		15	17	21
M		20	20	22
N	Barrel Metal	6	8	12
O	Inner tube rubber	11	13	18
P	Barrel Metal	11	13	18
Q	Wire (4 mm)	16	18	22
Handle	Wood pole			
Post	Wood post			

EVALUATION

Approximately three hundred pumps are now in use in Afghanistan where this design originated. The hand pump described here has proven to be a very efficient pump for lifting water short distances. The following table shows the pumping capacity for each size pump.

Diameter of pipe	Length of pipe	Height of lift	Gallons per minute at 6000' elevation
8 cm	450 cm	2 to 4 meters	30 gallons
10 cm	270 cm	1 to 2 meters	40 gallons
15 cm	140 cm	1 meter	75 gallons

Material From - Dale Fritz, The Asia Foundation

HANDLE MECHANISM FOR HAND PUMPS

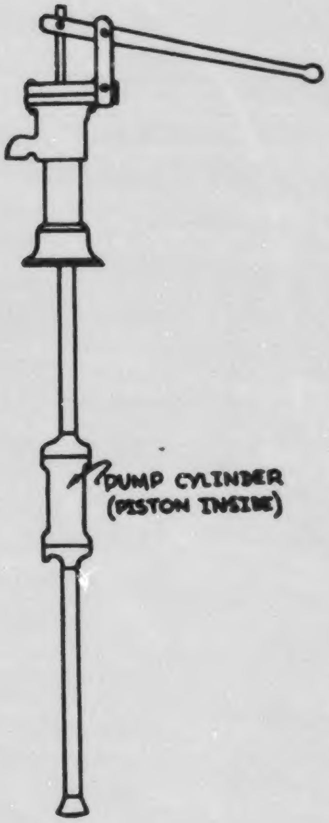


FIG. 2

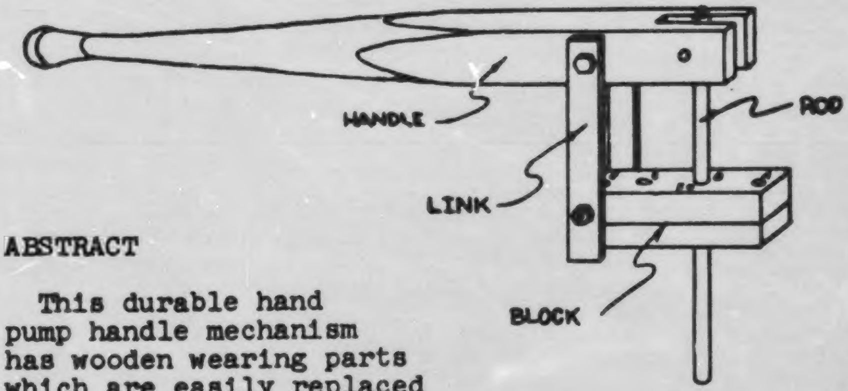


FIG 1

ABSTRACT

This durable hand pump handle mechanism has wooden wearing parts which are easily replaced by the village carpenter. It is designed to replace the handle mechanism of your pump.

TOOLS AND MATERIALS

Saw
Drill
Bits
1/2" tap
3/8" tap
Chisel
Drawknife, spokeshave, or lathe
43" x 2 1/2" x 2 1/2" Hardwood
16" of 3/4" diameter mild steel rod
2 pieces 10 1/2" x 1 1/2" x 1/4" strap iron

BOLT HARDWARE

# Bolts reqd.	Dia. inches	length inches	# nuts reqd.	# Lock-washers	# Plain washers	Purpose - fastens:
1	3/8	1 1/2	0	0	0	3" bolt to rod
1	3/8	3	0	0	2	Rod to Handle
2	1/2	3 1/2	2	4	4	Link to Handle Link to Block
2	1/2	?	2	2	2	Block to your pump
1	1/2	?	1	1	0	Rod to piston

DETAILS

If you have been having difficulty with maintenance on the handle mechanism of hand pumps, this design will help. The mechanism of Figure 1 is bolted to the top flange of your pump. The mounting holes A and C in the block are spaced to fit your pump. Figure 2 shows a pump with this handle mechanism already attached which is being manufactured by F. Humain and Bros., 28 Strand Road, Calcutta, India. The price for the pump is about Rs. 36, f.o.b. Calcutta, which is roughly $7.50. The major parts of the handle mechanism are described in the following paragraphs.

Handle - Make the handle of tough hardwood, shaped on a lathe or by hand shaving. The slot should be cut wide enough to accommodate the rod with two plain washers on either side. See Figure 3.

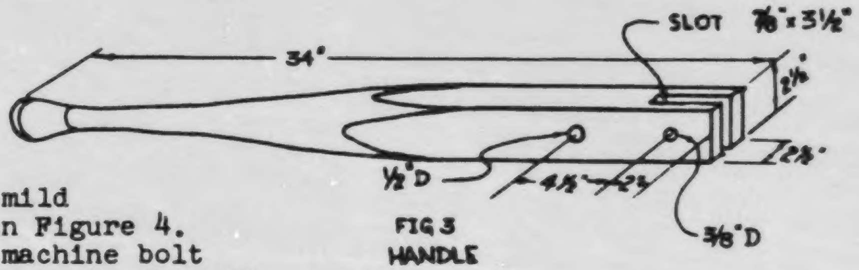


FIG 3
HANDLE

Rod - Made of mild steel as shown in Figure 4. A 3/8" diameter machine bolt 1 1/2" long screws into the end of the rod to lock the rod hinge pin in place. The rod hinge pin consists of a 3/8" diameter machine bolt. The piston can be bolted directly to the end of the rod using a 1/2" bolt. If the pump cylinder is too far down, a threaded 1/2" rod should be used instead of a bolt.

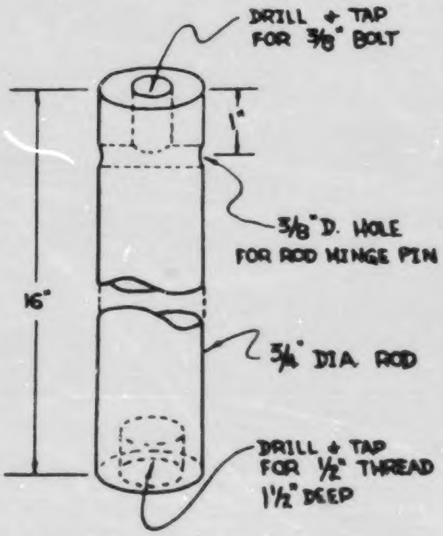

DRILL + TAP FOR 3/8" BOLT
1"
3/8" D. HOLE FOR ROD HINGE PIN
16"
3/4" DIA. ROD
DRILL + TAP FOR 1/2" THREAD 1 1/2" DEEP

FIG 4
ROD

Link - These consist of two pieces of flat steel strap iron. Clamp the pieces together for drilling in order to make the hole spacing equal. See Figure 5.

Block - The block forms the base of the lever mechanism, serves as a lubricated guide hole for the rod, and provides a means for fastening the mechanism to the pump barrel. If

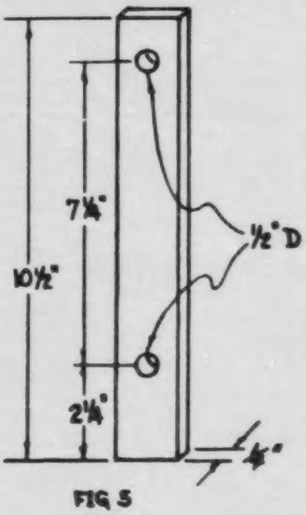


FIG 5
LINK

the block is accurately made of seasoned tough hardwood without knots, the mechanism will function well for many years. Carefully square the block to 9" x 2 1/2" x 2 1/2". Next holes A, B, C, and D are drilled perpendicular to the block as shown in Figure 6. The spacing of the mounting holes A and C from hole B is determined by the spacing of the bolt holes in the barrel flange of your pump. Next saw the block in half in a plane 1 3/8" down from the top side. Enlarge hole B at the top of the lower section with a chisel to form an oil well around the rod. A 1/4" hole, F, is drilled at an angle from the oil well to the surface of the block. A second oil duct hole E is drilled in the upper section of the block to meet hole D. Use lockwashers under the head and nut of the link bolts to lock the bolts and links together. Use plain washers between the links and the wooden parts.

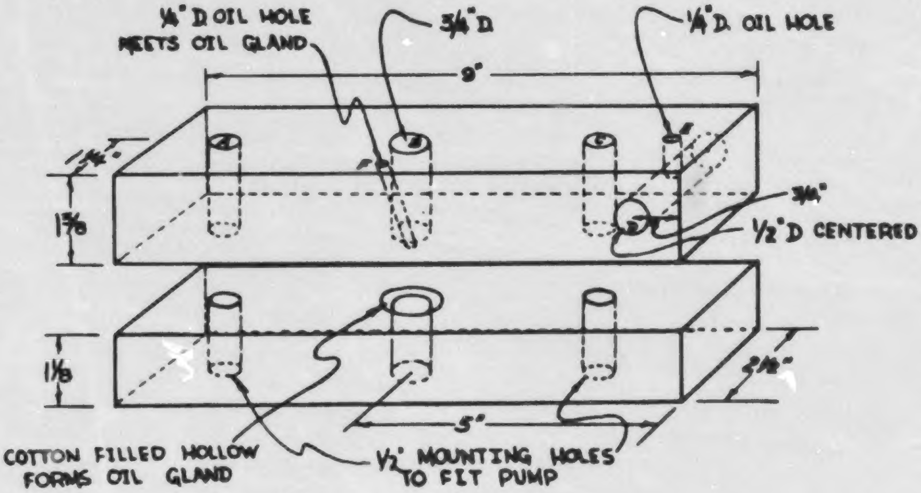

1/4" D OIL HOLE
MEETS OIL GLAND
3/4" D
1/4" D. OIL HOLE
9"
1 1/4"
1 3/8
3/4"
1/2" D CENTERED
1 1/8
2 1/2"
5"
COTTON FILLED HOLLOW
FORMS OIL GLAND
1/2" MOUNTING HOLES
TO FIT PUMP

FIG 6
BLOCK

EVALUATION

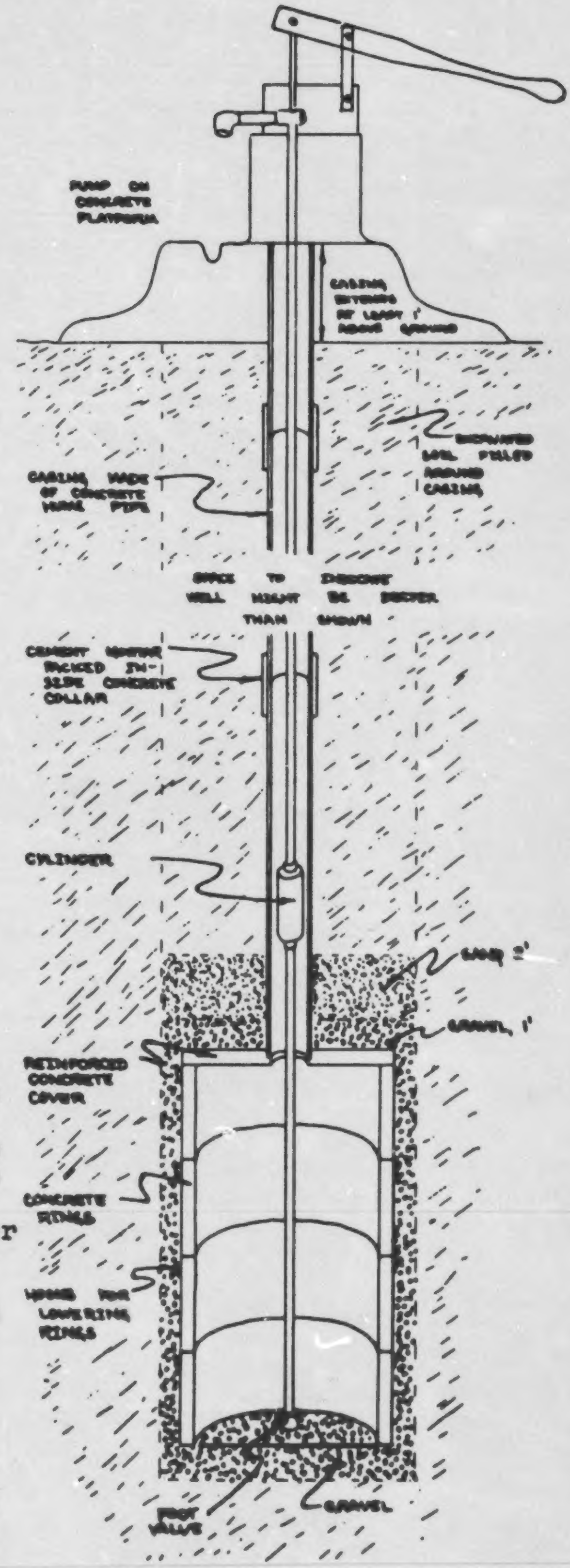
Dr. Abbott of the AFSC Barpali project, Orissa, India, has had 45 such pumps in operation for more than three years. Repairs have been simple and infrequent.

Material From - Dr. Edwin Abbott, M.D. (AFSC)

REFERENCE

A Pump Designed for Village Use by Dr. Edwin Abbott, M.D., available through VITA, 1206 State Street, Schenectady 4, New York

SEALED DUG WELL


PUMP ON CONCRETE PLATFORM
CASING EXTENDS AT LEAST 1' ABOVE GROUND
EXCAVATED SOIL FILLED AROUND CASING
CASING MADE OF CONCRETE HUME PIPE
SPACE TO INDICATE WELL MIGHT BE DEEPER THAN SHOWN
CEMENT MORTAR PACKED INSIDE CONCRETE COLLAR
CYLINDER
SAND 2'
GRAVEL, 1'
REINFORCED CONCRETE COVER
CONCRETE RINGS
HOOKS FOR LOWERING RINGS
FOOT VALVE
GRAVEL

ABSTRACT

This well has an underground concrete tank with a casing pipe instead of brick walls. Advantages are pure water, no hazard to children, ease of construction, small area required and low cost.

TOOLS AND MATERIALS

Four reinforced concrete rings with iron hooks for lowering, 3' diameter.
One reinforced concrete cover with seating hole for casing pipe.
Washed gravel to surround tank; 70 cubic feet.
Sand for top of well; 24 cubic feet
Concrete hume pipe, 6" diameter from top of tank cover to at least 1' above ground.
Concrete collars - as many as joints required in hume pipe.
Cement - 10 pounds for mortar for hume pipe joints.
Deep well pump and pipe
Concrete base for pump
Tripod, pulleys, rope for lowering rings.
Special tool for positioning casing when refilling, see text.
Digging tools, ladders, rope.

DETAILS

A village well must, in many places, act as a reservoir. This is because at certain hours of the day the demand is heavy, whereas during the night and the heat of the day there is no call on the supply. Thus it is calculated to make the well large enough to allow the water slowly percolating in to accumulate during the off use hours, in order to have an adequate supply when the demand on it is heavy. For this reason wells are usually made six or seven feet in diameter. Wells cannot store rainy season water for the dry season, and there is seldom sense in making a well larger in diameter than seven feet. The depth of a well is much more important than the diameter in determining the amount of water that can be drawn when the water level is low. A deep, narrow well will often provide more water than a wide shallow one. Remember that tubewells are much easier to construct than a dug well, and should be used if your region allows their construction and an adequate amount of water can be drawn from a tubewell during the busy hours.

The masonry lining of a deep dug well is very expensive. An open well, having organic matter falling into it from the surface and a continuous source of possible contamination from the various buckets lowered into it is very often contaminated. The tremendous quantity of soil removed from a deep well of reasonable diameter must be disposed of somewhere.

A villager in Barpali, India, working with the AFSC unit there suggested this radical new idea; to make a masonry tank at the bottom of the well, roof it over, and draw the water from it with a pump. The resulting sealed well has many advantages:

1. Provides pure water, safe for drinking.
2. Presents no hazard of children falling in.
3. Drawing water is easy, even for small children.
4. The well occupies little space, a small courtyard can accommodate it.
5. The cost of installation is greatly reduced.
6. The labor involved is much reduced.
7. There is no problem of getting rid of excavated soil, since most of it is replaced.
8. The casing enables the pump and pipe to be easily removed for servicing.
9. The gravel and sand surrounding the tank provide an efficient filter to prevent silting, allows a large surface area for percolating water to fill the tank, and increases the effective stored volume in the tank.

On the other hand, there are two minor disadvantages--only one person can pump at one time, and the pump might go out of order. In addition, there is a certain amount of technical skill required to make the parts used in the well and to install them properly.

A well is dug four feet in diameter and about thirty feet deep. The digging should be done in the dry season, after the water table has dropped to its lowest level. There should be a full 10 feet re-accumulation of water within 24 hours after the well has been bailed or pumped dry. Greater depth is, of course, desirable.

Six inches of clean, washed gravel or small rock is spread over the bottom of the well; the four rings and cover are lowered into the well and positioned there. Lowering of the rings to form the tank requires setting up a tripod of strong poles and block and tackle since the rings weigh about 400 pounds each. The rings and cover form a tank six feet high and three feet in diameter with a round opening in the top which forms a seat for the casing pipe and allows the suction pipe to penetrate to about six inches from the gravel bottom.

The first section of concrete hume pipe is positioned in the seat and grouted in place. It is braced vertical by a wooden plug with four hinged arms to brace against the sides of the wall. More gravel is packed around the concrete rings and over the top of the cover till the gravel layer above the tank is at least six inches deep. This is then covered with two feet of sand. Soil removed from the well is then shoveled back until filled within six inches of the top of the first section of casing. The next section of casing is then grouted in placed, using a concrete collar made for this purpose. The well is filled and more sections of casing added until the casing extends at least one foot above the surrounding soil level.

The amount of soil which will not pack back into the well can make a shallow hill around the casing to encourage spilled water to drain away from the pump. A concrete cover is placed on the casing and a pump installed.

If concrete or other casing pipe cannot be obtained, a chimney made of burned bricks and sand-cement mortar will suffice. The pipe is somewhat more expensive, but much easier to install.

In India, the concrete rings are being made for about Rs. 10 each, the cover for 15, the pump platform for 10, and the casing at Rs. 2 per foot. Thus for a 25 foot well, the materials cost Rs. 115. The pump, pipe, cylinder, fittings etc. to complete the well cost about an equal amount. Thus the whole installation, without figuring the labor, costs Rs. 230, or about $50.00. In India, the AFSC group is charging Rs. 40 for installation of such a well, which would cover labor. The Service Committee actually uses this money to buy a set of tools which are given to the villager after he has received training in well and pump maintenance.

EVALUATION

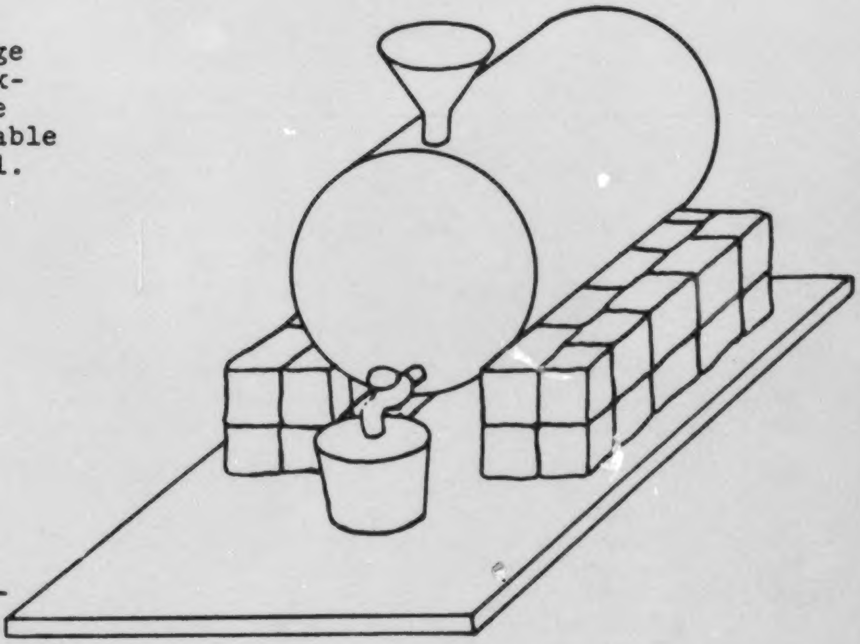
Over 45 wells of this type have been installed in India by the AFSC team there, and all have performed perfectly for several years except one that was not dug deep enough.

Material From - "A Safe Economical Well," AFSC,
Barpali Village Service

BOILER FOR POTABLE WATER

ABSTRACT

To provide safe storage and preparation of drinking water in areas where pure water is not available and boiling is practical.



TOOLS AND MATERIALS

- 1 - 55 Gallon drum
- 1 - 3/4" Pipe Nipple 2" long. Quantity of bricks for two 1 layers of bricks to support drum.
- 1 - Bag of cement plus sand for mortar and base of fireplace.
- 1 - large funnel and filter medium for filling.
- 1 - Metal plate to control draft in front of firebox.
- 1 - 3/4" Valve, preferably all metal such as a gate valve to withstand heat.

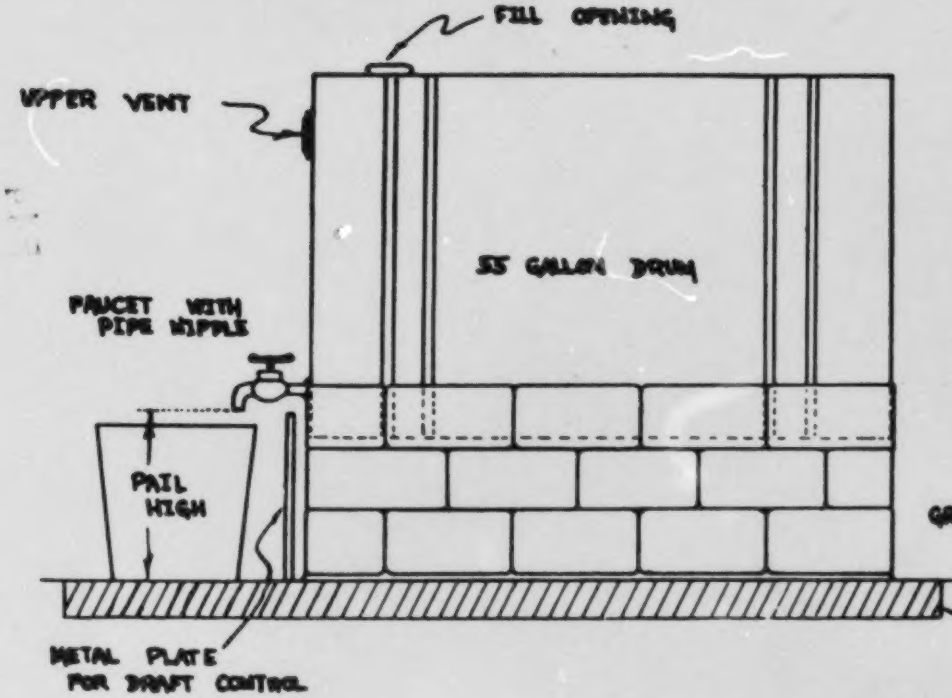
DETAILS

This drum for boiling of drinking water is intended for use in your residence to provide a convenient method for preparation and storage of sterile water. The fireplace is simple, oriented so that the prevailing wind or draft goes from front to back of the drum between the bricks. A chimney can be provided but is not necessary.

EVALUATION

The unit has been tested in many Friend's workcamps in Mexico and elsewhere. A 55 gallon drum would normally last a 20 person camp group for an entire week, and certainly would provide adequate safe water supply for two or three individuals for a much longer time. Water must boil at least 15 minutes with steam escaping around the completely loosened filler plug. Be sure that the water in the pipe nipple and valve reach boiling temperatures by purging about two liters of water out through the valve while the drum is at a full boil.

Material From - Chris Ahrens, CARE-PEACE CORPS


FILL OPENING
UPPER VENT
55 GALLON DRUM
FAUCET WITH PIPE NIPPLE
PAIL HIGH
METAL PLATE FOR DRAFT CONTROL

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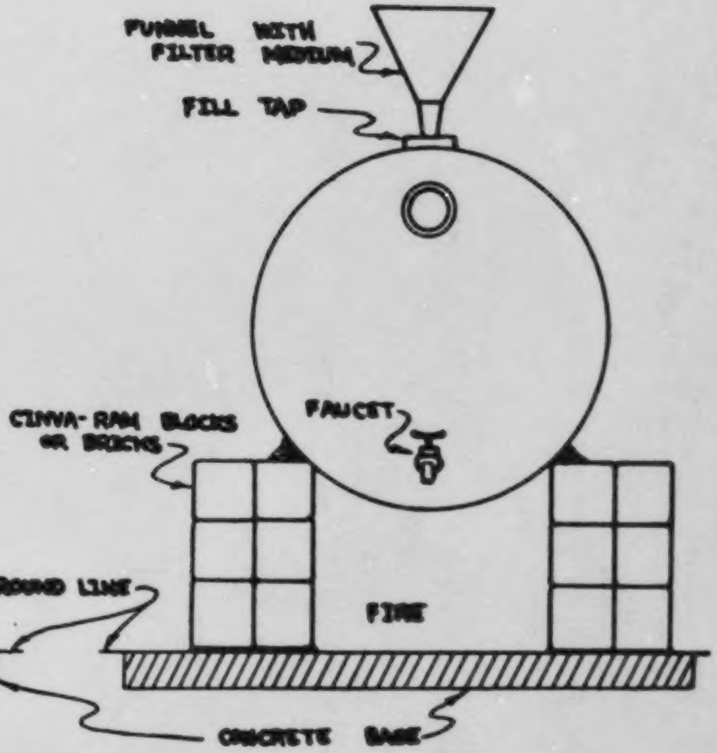
FUNNEL WITH FILTER MEDIUM
FILL TAP
FAUCET
CINVA-RAM BLOCKS OR BRICKS
GROUND LINE
FIRE
CONCRETE BASE

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Thus, depending on your water, different amounts of chlorine are needed for adequate protection. Measuring the amount of free chlorine after the 30 minute holding period is the best way to control the process. A simple chemical test using a special organic indicator (orthotolidine) can be used. When this is not available, the chart (Figure 1) can be used as a rough guide.

Water Condition	Initial Chlorine Dose in Parts Per Million(ppm)	
	No hard-to-kill organisms suspected.	Hard-to-kill organisms present or suspected.
Very Clear, few minerals.	5 ppm	Get expert advice; in an emergency boil and cool water first, then use 5 ppm to help prevent recontamination. If boiling is impossible, use 10 ppm.
A coin in the bottom of an 8 oz. glass of the water looks hazy.	10 ppm	Get expert advice; in an emergency boil and cool first. If boiling is impossible use 15 ppm.

FIGURE 1

In the chart, parts per million or "ppm" means the ratio of:

$$\frac{\text{Weight of active material (chlorine)}}{\text{Weight of water}}$$

In water supply terminology, ppm means exactly the same thing as milligrams per liter or "mg/l".

The second chart, Figure 2, gives the amount of chemical to add to 1000 gallons of water to get a solution of 1 ppm. Multiply the amount of chemical shown in Figure 2 by the number of ppm recommended in Figure 1 to get the amount of chemical you should add to 1000 gallons of water. Usually it is convenient to make up a solution of 500 ppm strength which can then be further diluted to give the chlorine concentration needed. The 500 ppm solution must be stored in a sealed container in a cool dark place, and should be used as quickly as possible since it does lose strength. Modern chlorination plants use bottled chlorine gas, but this can only be used with expensive machinery by trained experts.

CHLORINATION FOR POLLUTED WATER

ABSTRACT

Chlorination, when properly applied, is a simple way to insure and protect the purity of water. These guidelines include tables to give a rough indication of the amounts of chlorine bearing chemicals needed.

TOOLS AND MATERIALS

Chlorine in some form
Container to mix chlorine

DETAILS

The surest way to treat water for drinking is to boil it--see "Boiler for Potable Water." However, under controlled conditions chlorination is a safe method, and often more convenient and practical than boiling. Water properly treated has residual free chlorine which resists recontamination. The chlorine in water is not harmful, since water with a harmful amount of chlorine in it is extremely distasteful. Proper treatment of water with chlorine requires some knowledge of the process and its effects.

When chlorine is added to water, it attacks and combines with any suspended organic matter as well as some minerals such as iron. There is always a certain amount of dead organic matter in water, and almost always live bacteria, virus, and perhaps other types of life. Enough chlorine must be added to oxidize all of the organic matter, dead or alive, and to leave some excess uncombined or "free" chlorine.

Some organisms are more resistant to chlorine than others. Two particularly resistant varieties are amebic cysts (which cause amebic dysentary) and the cercariae of schistosomes (which cause schistosomiasis). These, among others, require much higher levels of residual free chlorine and longer contact periods than usual to be safe. Often special techniques are used to combat these and other specific diseases. It always takes time for chlorine to work. Be sure that water is thoroughly mixed with an adequate dose of the dissolved chemical, and that it stands for at least 30 minutes before consumption.

Since both combined and uncombined chlorine has an unpalatable taste, it is best (and safest) to choose the clearest water available. A settling tank, and simple filtration can help reduce the amount of suspended matter, especially particles large enough to see. Filtration that can be depended upon to remove all of the amebic cysts, schistosomes, and other pathogens normally requires professionals to set up and operate. NEVER depend on home-made filters alone to provide potable water. However, a home-made slow sand filter is an excellent way to prepare water for chlorination.

Compound	% by weight of active material	Quantity to add to 100 gallons of water to get a 1 ppm solution
High Test (Calcium hypochlorite) $Ca(OCl)_2$	70%	1/5 ounce
Chlorinated lime	25%	1/2 ounce
Sodium hypochlorite NaOCl	14%	1 ounce
Sodium hypochlorite	10%	1.3 ounces
Bleach - a solution of chlorine in water	usually 5.25%	2.6 ounces

FIGURE 2

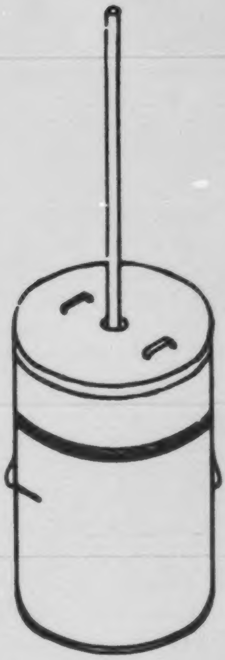
HAND WASHING MACHINE

ABSTRACT

This hand washer is simple to construct and simplifies washing considerably.

TOOLS AND MATERIALS

Tinsnips
Pliers
Hammer
Soldering equipment
Galvanized iron sheeting: 140 cm x 70 cm for tub
100 cm x 50 cm for lid and bottom
36 cm x 18 cm for agitator
Wooden handle - 4 cm diameter, 140 long



DETAILS

The tub, lid and agitator are made of the heaviest galvanized tin available which can be worked by a tinsmith.

To operate the washing machine the agitator is worked up and down with a quick motion but with a slight pause between strokes. The movement of the water caused by the agitator will continue for a few seconds before additional agitation is needed. On the upward stroke the agitator should come completely out of the water. The agitator should not hit the bottom of the tub on the downward stroke as this would damage both the tub and the clothes.

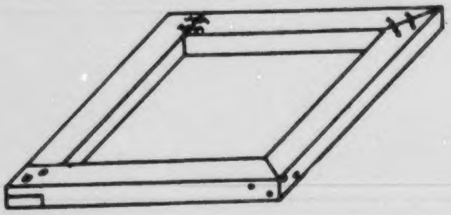
SILK SCREEN PRINTING

ABSTRACT

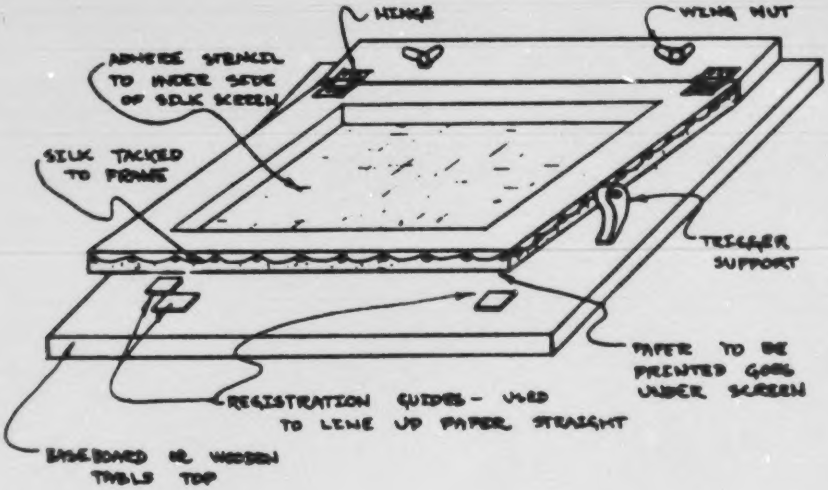
Silk screen printing is a simple and inexpensive method for producing multiple copies of visual aids, posters, etc. A squeegee is used to force very thick paint through the parts of the silk screen exposed by the stencil to the paper placed underneath.

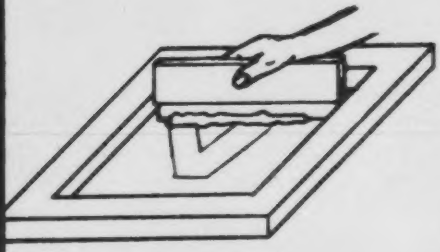
TOOLS AND MATERIALS

Hinges (about 1" x 3")
Wing or regular nuts
Squeegee
Trigger support
Frame
Baseboard or smooth table top
Silk or other sheer cloth
Thumbtacks
Silk screen paint
Paper for copies

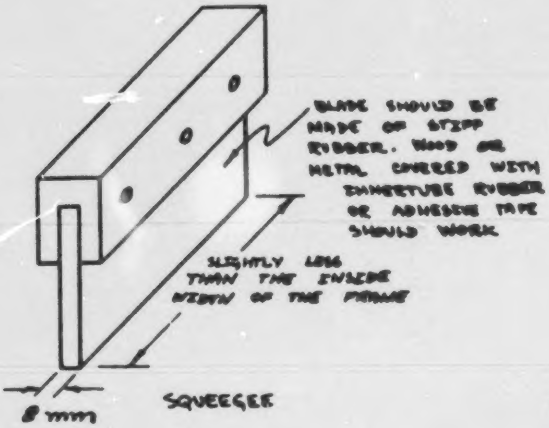


FRAME
SHOWING VARIOUS JOINT CONSTRUCTIONS


HINGE
WING NUT
ADHERE STENCIL TO UNDER SIDE OF SILK SCREEN
SILK TACKED TO FRAME
TRIGGER SUPPORT
PAPER TO BE PRINTED GOES UNDER SCREEN
REGISTRATION GUIDES- USED TO LINE UP PAPER STRAIGHT
BASEBOARD OR WOODEN TABLE TOP



SQUEEGEEING PAINT ACROSS SILK


BLADE SHOULD BE MADE OF STIFF RUBBER. WOOD OR METAL COVERED WITH INNERTUBE RUBBER OR ADHESIVE TAPE SHOULD WORK
SLIGHTLY LESS THAN THE INSIDE WIDTH OF THE FRAME
8 mm

SQUEEGEE

DETAILS

1. Study the drawings, then construct a frame as illustrated using approximately (1.9 x 5 cms.)(3/4" x 2") plywood or other wood. The exact size of the frame is determined by the size of the largest prints to be made. Average inside frame dimensions might be (38.1 cm. x 50.8 cm.)(18" x 24"). Make sure the corners are square and that the frame lies flat against a flat baseboard or table top, which can also be made of 1.9 cm (3/4") plywood.

2. Stretch the silk very tightly over the underside of the frame using tacks or thumb tacks every 1" or 2 cm. Tack either in the center of the underside of the frame or pull the silk over the outside bottom edges and tack around the outside. Make sure that the threads of the fabric are lined up with the frame edges. A few coats of shellac over wooden frame will make it more durable and less apt to warp.

3. Cut stencil and adhere to screen according to instructions.

4. Place the paper cardboard, etc, to be printed under the screen and stencil; draw a couple of spoonfulls of finger paint or other water-soluble paint in a line across the edge of the silk just inside one end of the frame.
(Oil soluble paints work well, but require a solvent cleanup; also, the viscosity of the paint should be like auto transmission grease, not thin enough to fall through the screen of its own accord.)

5. Pull the paint across the silk surface using an edge of the squeegee blade. This squeezes the paint through all the open areas of the paper stencil. Lift screen. Remove print and replace with next piece to be printed. Pull paint back the other way for the next print. The desired technique is to place an amount of paint on the screen which, together with the right blade pressure, will produce an acceptable print with one stroke of the squeegee.
Make certain that dried paint particles do not get in the paint as they could damage the screen.

6. If more than one color is to be printed, registration becomes an important feature and can be achieved by the following method:

(a) Print the first color using registration guides. Registration guides can be made of thin cardboard or several layers of tape. (Thicker guides can cause silk to break when squeegee blade presses the silk against the guides.)

(b) A piece of wax or thin translucent paper is taped on one edge to the baseboard beneath the second screen to be printed.

(c) Print a trial image of the second screen onto this paper.

(d) Raise the screen.

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(e) Slide the sample of the first printing into position beneath the taped wax paper until the desired registration with the first printing is achieved.

(f) Once registered carefully hold the first printing sample in position, and remove the wax paper.

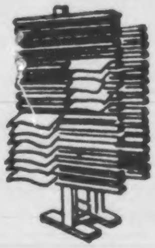
(g) Tape new registration guides on three sides of the first printing sample.

(h) Now proceed to print the second color. Subsequent colors are printed by returning to Step (b).

7. Several colors can be printed over one another if transparent paints are used. The size of the printed area can be restricted by using paper masks.

8. Pull off stencil. Clean wet paint out of silk and frame by unscrewing wing bolts, taking the frame to a convenient wash area and holding under running water.

9. Optional: A drying rack pictured here is helpful when many prints are to be dried.



DRYING RACK MADE WITH 2" x 2" UPRIGHTS WITH 1" x 1" CROSS BARS ABOUT AN INCH APART

BAMBOO OR REED WRITING PENS

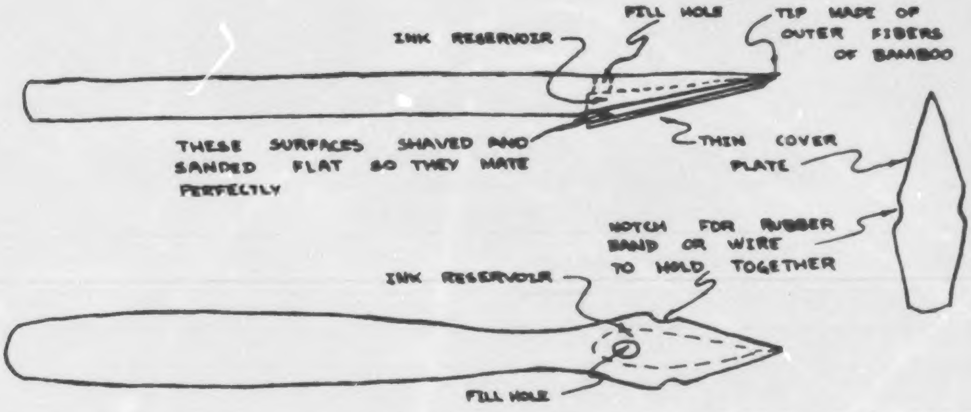
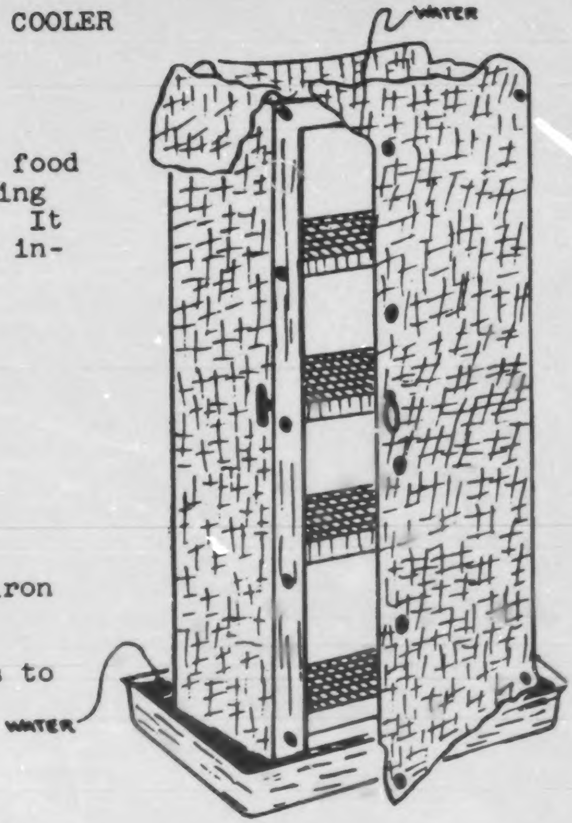

FILL HOLE
TIP MADE OF OUTER FIBERS OF BAMBOO
INK RESERVOIR
THESE SURFACES SHAVED AND SANDED FLAT SO THEY MATE PERFECTLY
THIN COVER PLATE
NOTCH FOR RUBBER BAND OR WIRE TO HOLD TOGETHER
INK RESERVOIR
FILL HOLE

FIG. 3

EVAPORATIVE FOOD COOLER



ABSTRACT

In warm, dry climates an evaporative food cooler will extend the period for keeping food fresh and allow saving leftovers. It also helps to keep crawling and flying insects away from food.

TOOLS AND MATERIALS

Saw
Hammer
Nails, tacks
Burlap or other cloth 2 m. x 2 m.
Wood for frame 3 cm x 3 cm x 13 m.
Pan 10 cm deep, 24 x 30 cm for top.
Screen, hardware cloth or galvanized iron 2 m. x 2 m. (non-rusting)
2 pair hinges
Pan larger than 30 cm x 36 cm for legs to stand in
Paint for wooden parts

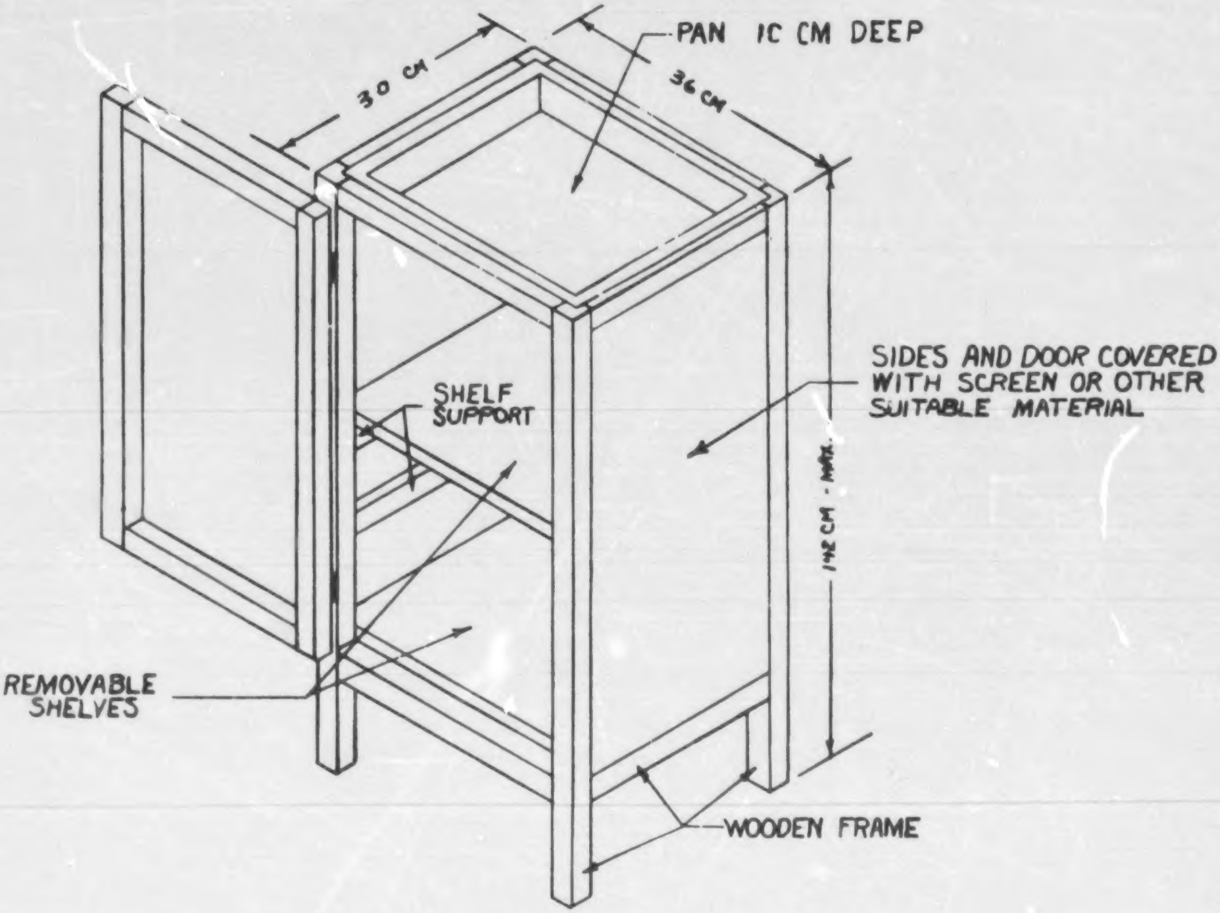
DETAILS

Make the wooden frame to fit the upper pan. This might be the bottom of a discarded 5 gallon oil can. Screen and bracing sticks on the inside top of the frame prevent the pan from falling into the refrigerator. Hinge the door carefully so it swings easily, and make a simple wooden or thong latch. Paint or oil all the wooden parts. Shelves and frame are covered with screening or hardware cloth and tacked in place. Cutting this screen diagonally uses a bit more material, but will strengthen the frame considerably. Make the shelves adjustable by providing several shelf supports.

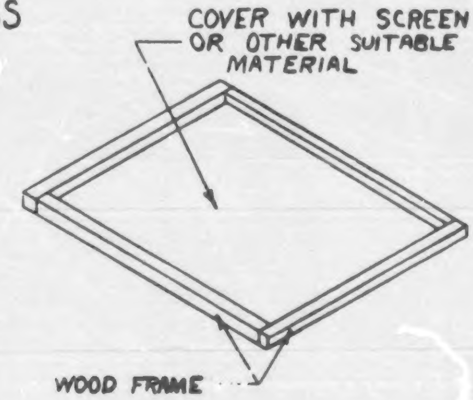
Two covers of canton flannel, jute burlap (not sisal or henequin burlap) or heavy grade absorbent coarse cloth are made to fit the frame. Wash and sun one cover while using the other. Button or lace the cover to the frame, with the smooth side out. On the front, fasten the cover to the door instead of the frame. Allow a wide hem to overlap the door closing. The bottom of the cover should extend down into the lower pan. Strips 20 cm wide should be sewed to the top of the cover. These form wicks that dip over into the upper pan. Keep both the upper and lower pans filled with water.

EVALUATION

If the cooler is kept in a breezy spot in the shade, and the climate is dry, it will cool food considerably. The cover keeps flying insects out, while the lower pan discourages roaches and other crawling types. To be safe, the cooler must be kept clean.


PAN 10 CM DEEP
30 CM
36 CM
SIDES AND DOOR COVERED WITH SCREEN OR OTHER SUITABLE MATERIAL
SHELF SUPPORT
142 CM - MAX.
REMOVABLE SHELVES
WOODEN FRAME

FRAME OF ICELESS REFRIGERATOR


COVER WITH SCREEN OR OTHER SUITABLE MATERIAL
WOOD FRAME

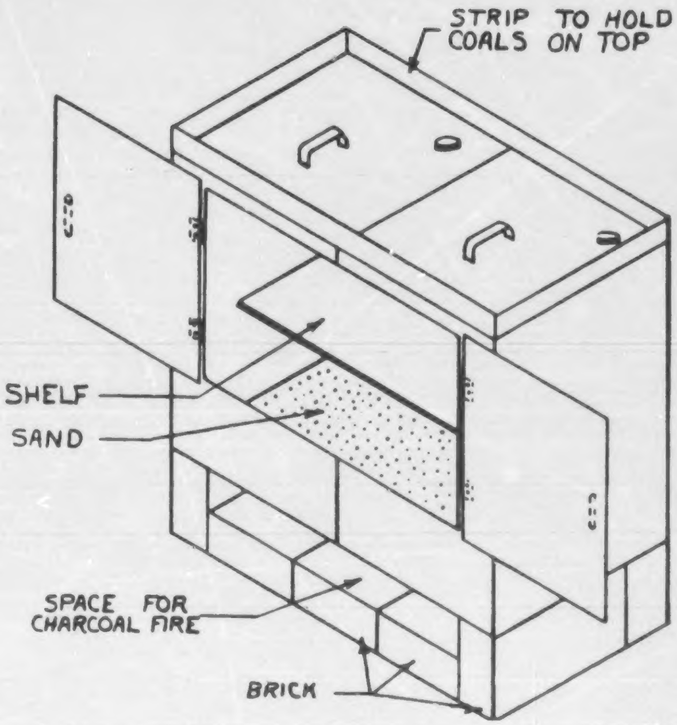
SHELF

Material From - A.I.D. publications

CHARCOAL OVEN

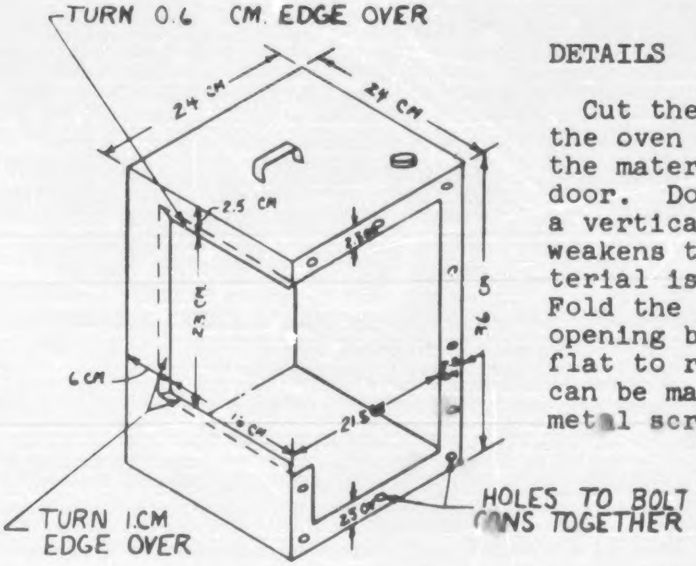
ABSTRACT

This simple charcoal-fired oven is made from two discarded 5 gallon oil tin cans. With practice, all types of baking can be expertly done.


STRIP TO HOLD COALS ON TOP
SHELF
SAND
SPACE FOR CHARCOAL FIRE
BRICK

TOOLS AND MATERIALS

Nail for scriber and punch
Tinsnips
Heavy knife to start cuts
Hammer
Screwdriver
Pliers
Metal bar 20 cm long with square corner for bending
Two 5 gallon oil cans
Tin cans to provide shelf material
Light rod 50 cm long, 5 to 7 mm diameter
Two pairs of light hinges
12 machine bolts, nuts, lockwashers, size 8-32 or soft rivets
Bricks for base
Sand


TURN 0.6 CM. EDGE OVER
24 CM
24 CM
2.5 CM
2.5 CM
23 CM
5
36
6 CM
15 CM
21.5
2.5 CM
TURN 1.CM EDGE OVER
HOLES TO BOLT CANS TOGETHER

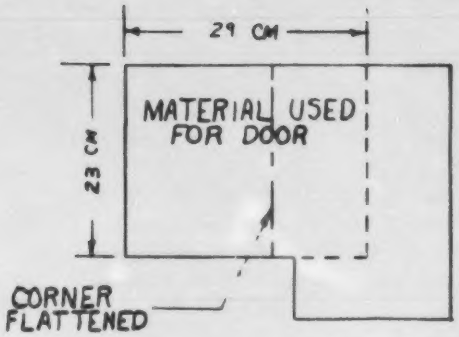
NOTE: OTHER CAN IS CUT REVERSE OF THE ABOVE CAN.

DETAILS

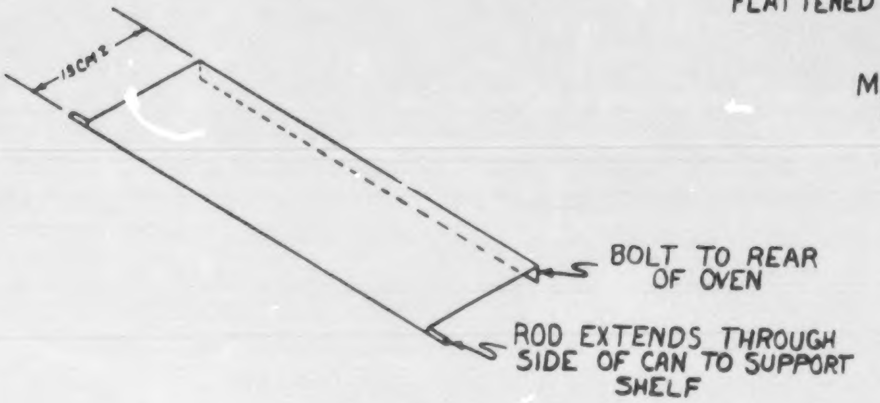
Cut the material from the side of the oven with care so as to preserve the material removed for making the door. Don't cut out the corner with a vertical seam; it is to hard to do, weakens the oven, and the revoved material is hard to make into the doors. Fold the edges of the door and door opening back (1 cm wide) and hammer flat to remove sharp edges. The latch can be made of three thicknesses of metal scraps left over. Clean the oven thoroughly and heat at least once before baking to burn out any residual oil. The strip around the top forms a rim to contain burning coals, to make the oven hotter, or to brown the surface of baked goods.

EVALUATION

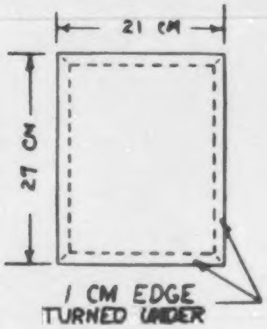
This oven is being used successfully in a number of countries. Baking and roasting are quite effectively done with this simple and inexpensive appliance. Any recipes which involve these processes may be used.


29 CM
23 CM
MATERIAL USED FOR DOOR
CORNER FLATTENED

MATERIAL CUT FROM CAN


13CM ±
BOLT TO REAR OF OVEN
ROD EXTENDS THROUGH SIDE OF CAN TO SUPPORT SHELF

SHELF


21 CM
27 CM
1 CM EDGE TURNED UNDER

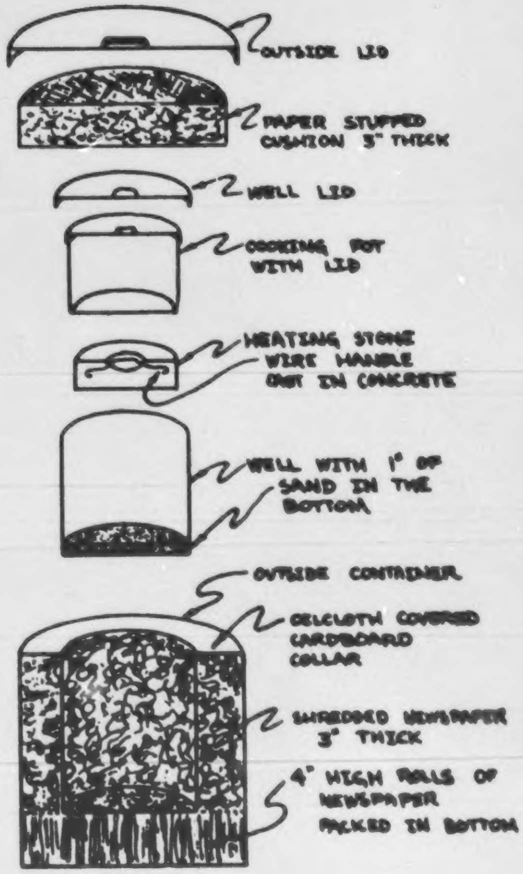
DOOR

Material From - V. C. Pettit, I.C.A.-AID

FIRELESS COOKER

ABSTRACT

In some places where fuel is scarce, this easy-to-build fireless cooker can be a real contribution to better cooking. It works by heat retention through insulation.


OUTSIDE LID
PAPER STUFFED CUSHION 3" THICK
WELL LID
COOKING POT WITH LID
HEATING STONE
WIRE HANDLE CAST IN CONCRETE
WELL WITH 1" OF SAND IN THE BOTTOM
OUTSIDE CONTAINER
OILCLOTH COVERED CARDBOARD COLLAR
SHREDDED NEWSPAPER 3" THICK
4" HIGH ROLLS OF NEWSPAPER PACKED IN BOTTOM

TOOLS AND MATERIALS

Outside container with lid - (15" to 24" in diameter)
Inside container or well - at least 6" smaller in diameter and 6" shorter than outside container
Cooking pot with lid
1 1/2 yards cloth for cushion
50 sheets newspaper or other insulation.
Cardboard
6 cups sand
4 cups cement
1/2 yard oilcloth for collar (optional)

DETAILS

The principle of the fireless cooker is to keep food cooking with the small amount of heat stored in hot stones by preventing heat loss with a thick layer of insulating material around the pot.

The outside container can be a wooden bucket, kerosene can, garbage can, packing crate or even a hole in dry ground. The inside container or well can be a pail or can with a lid. It must allow for the three inches of insulation between it and the outside container and should hold the stone and cooking pot without much vacant space.

Insulation can be made of shredded newspapers, wool, cotton, sawdust, straw, rockwool, fiberglass or other material. The insulation should be at least three inches thick on all sides, top and bottom. Be sure that it is very dry. The bottom layer of insulation must be strong enough to support the weight of the well, stone, and cooking pot. A natural stone carved to shape or a piece of concrete may be used for the heating stone. The cushion is a three-inch-thick cloth sack filled with shredded newspapers or other insulation and should fit snugly in the outside container. The cooking pot must have a tight lid, and fit nicely into the well with the stone in place. Be sure it can be easily removed when full of hot food.

Direction for building -

Wash and dry the containers and lids.

Cut 4" wide strips of newspaper several layers thick. Roll each into a cylinder with a center hole no greater in diameter than a pencil. Pack these on end into the bottom of the outside container. They will support the well, stone, and cooking pot.

Put the well in place and pack the insulation around it to within 1/2" of the top.

Make a cardboard collar covered with oilcloth. Though this is not necessary, it improves appearance and cleanliness.

Place about an inch of clean sand in the bottom of the well. This will prevent the hot stone from scorching the paper rolls and possibly causing a fire. The stone should never be heated not enough to scorch paper.

To make a concrete heating stone, place a 2" wide cardboard band or collar on heavy paper or board to form a circle the size of the stone desired. Mix 4 cups each of cement and sand washed free of silt, then add 1 1/2 cups of water or until a stiff mush is formed. Fill the collar, casting in a wire handle for lifting the hot stone. Let the stone stand for 48 hours, then remove the collar, place it in cold water and boil for 30 minutes. Cool it slowly.

Use of the Cooker -

It is important to keep the cooking pot and well carefully washed and open, in sunshine if possible, when not in use. The cooker's lid should be left partly open and the stone kept clean and dry.

It is not necessary to use much water when cooking in a fireless cooker for there is little loss by evaporation. Most foods should be brought to a boil and cooked for 4 to 5 minutes on a stove. Then, the covered cooking pot is set on the hot stone in the cooker and the lid is placed on the well. Cereal may be left in the cooker all night. Rice and cracked or whole wheat are especially good. Beans should be soaked over night, boiled for 5 minutes and then placed in the cooker for 4 to 5 hours. Dried fruit should be washed, soaked for an hour in 2 parts water to 1 part fruit, boiled for 5 minutes, then placed in the cooker for 4 hours.

EVALUATION

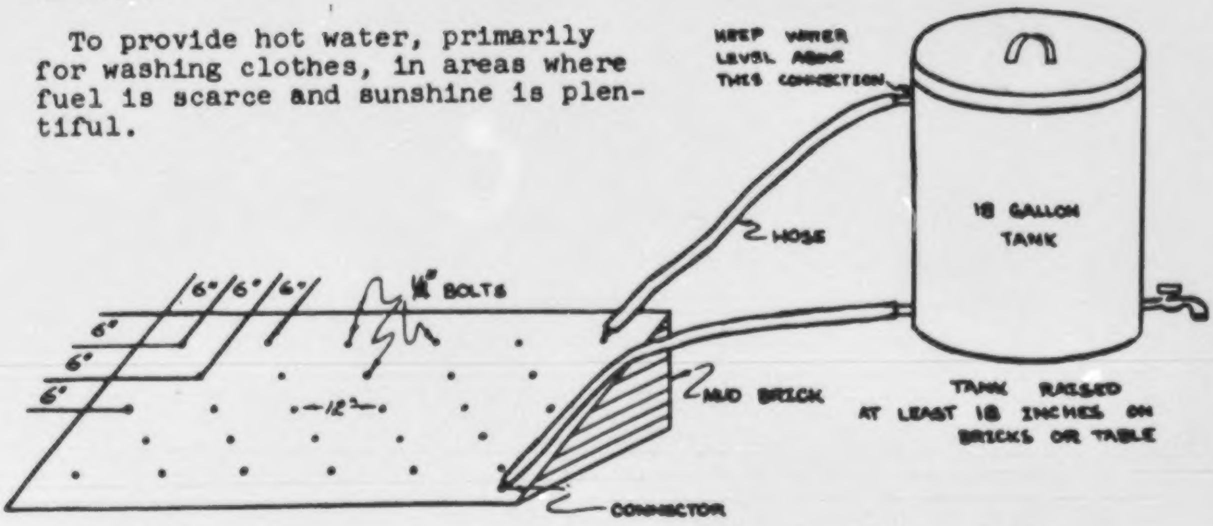
Fireless cookers have been used and found very successful in many countries.

Material From - "Home Making Around the World"
A.I.D. publication.

SOLAR WATER HEATER

ABSTRACT

To provide hot water, primarily for washing clothes, in areas where fuel is scarce and sunshine is plentiful.

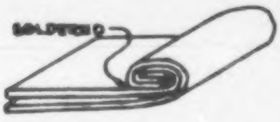

KEEP WATER LEVEL ABOVE THIS CONNECTION
18 GALLON TANK
HOSE
6"
6"
6"
6"
6"
6"
1/4" BOLTS
12"
MUD BRICK
TANK RAISED AT LEAST 18 INCHES ON BRICKS OR TABLE
CONNECTOR

TOOLS AND MATERIALS

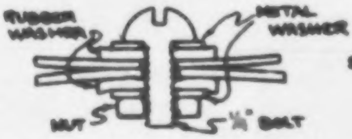
2 pieces galvanized sheet metal, 3' by 6' for heater.
2 pieces galvanized sheet metal pipe, 6" long by 1" in diameter for connectors.
2 pieces rubber hose, 4' long by 1" in diameter.
56 metal washers for 1/4" bolts.
56 rubber washers cut from heavy truck inner tube. Inside hole diameter should be 1/8", outside diameter same as metal washers.
28 stove bolts, galvanized, 1/4" long.
1 galvanized sheet metal tank, 18 gallon capacity with faucet, removable lid, 1" hose connectors near the top and bottom.
Tinsmith's tools: hammers, anvils, soldering equipment, etc.
Drill and 1/4" bit.
Screw driver and wrench to fit 1/4" bolts or a pair of pliers.
Quantity of mud bricks.

DETAILS

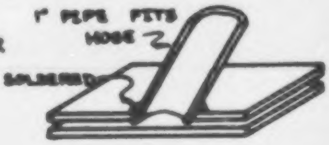
The heater is made by placing the two sheets of galvanized sheet metal together in the form of an envelope. The edges of the sheets are double folded and soldered to make an air tight seal. (See detail below.) To prevent the sheets from being forced apart when the heater is filled with water, it is necessary to reinforce it



EDGE FOLD


RUBBER WASHER
METAL WASHER
NUT
1/4" BOLT

BOLT AND WASHERS


1" PIPE FITS HOSE
SOLDERED

CONNECTOR

with 1/4" bolts placed at regular intervals, like buttons in a mattress. To make the bolts water-tight they must have rubber and metal washers on both sides. (See detail on page 153.)

Inlet and outlet connections are provided in the upper and lower right hand corners of the heater for connection to the tank. The front of the heater is painted black to absorb the sunlight rather than reflect it. A flat black paint is better than an enamel.

The tank does not have to be of any definite shape but should hold approximately 18 gallons of water. The hot water will rise to the top and, with the removable lid, it is possible to dip out the hottest water when only a small quantity is needed. When all of the water is to be used it may be drained out of the faucet. The water level must be maintained above the upper hose connection.

When the solar water heater is set up, the heater should be facing southeast to take advantage of the morning sun. The back of the heater should be raised about 18" so the sunlight will strike it as directly as possible. A simple way to raise the heater is to build up the back and sloping sides with mud bricks. Use three small boards (2" by 4") to prop up the back while putting the mud bricks in place. Then, remove the boards and seal any holes with mud to form a dead air space under the heater which will serve as insulation and increase the efficiency.

The heater is connected to the tank in such a way as to allow the water to circulate as it is heated. The upper connectors of the tank and heater are connected with one hose and the lower connectors with the other. The tank is raised approximately 18", using a small table or a brick platform, so the coolest water will be in the heater. As the water in the heater is warmed, it rises and flows out the upper hose into the top of the tank. Cool water from the bottom of the tank enters the heater at the bottom. Insulating the tank will increase the efficiency of the solar water heater by cutting down the heat losses. Any suitable local material may be used, such as straw or sawdust.

EVALUATION

The solar water heater described here was made and tested in Kabul, Afghanistan, for the purpose of providing hot water for use in the hand operated washing machine. Three sizes were made and tested: 2 1/2' x 4 1/2', 3' x 6', and 3' x 8' which are the sizes of sheet metal available in Kabul. The 3' x 6' heater with an 18 gallon tank was most suitable from the standpoint of cost and water requirement. In Kabul, where there is lots of sunshine, the 18 gallons of water were heated to 140° F. between sunup and noon on a clear summer day.

The cost of the solar water heater was $15.00 at prices paid for material and labor in Kabul during the summer of 1961.

Material From - Dale B. Fritz, The Asia Foundation

HAND-OPERATED WASHING MACHINE

ABSTRACT

This easily operated washing machine can be built by a semi-skilled carpenter of materials readily found in most countries. It can wash six pounds of clothes, can be shared by several families, and is easy on clothes while being effective and sanitary.

TOOLS AND MATERIALS

Tub Construction - Moderately firm softwood (such as Cedro of South America) free from large heartwood growth.

2 pieces - 2.5 x 45.7 x 96.5 cm. - sides
1" x 18" x 38"
2 pieces - 2.5 x 30.5 x 40.6 cm. - ends
1" x 12" x 16"
2 pieces - 2.5 x 15.2 x 40.6 cm. - bottom
1" x 6" x 16"
1 piece - 2.5 x 40.6 x 66.0 cm. - bottom
1" x 16" x 26"
4 pieces - 2.5 x 10.2 x 76.2 cm. - legs
1" x 4" x 30"
2 pieces - 2.5 x 25.4 cm. diameter - round plungers
1" x 10" diameter
2 pieces - 3.8 x 12.7 cm. diameter - round plungers
1.5"x 5" diameter
2 pieces - 2.5 x 20.3 x 91.4 cm. - cover (may be omitted)
1" x 8" x 36"
6 pieces - 2.5 x 7.6 x 20.3 cm. - cover (may be omitted)
1" x 3"x 8"

Operating parts - Moderately firm hardwood such as Caoba of South America.

1 piece - 2.5 x 7.6 x 121.9 cm. long - lever
1" x 3" x 48"
2 pieces - 2.9 cm. square 38.1 cm. long-plungers
1 1/8" square 15" long
2 pieces - 2.9 x 7.6 x 61.0 cm. long - uprights
1 1/8" x 3" x 24" long
2 pieces - 3.2 cm. round 45.7 cm. long - pivot and handle
1 1/4" round 18" long

Metal Parts

4 pieces iron or brass plate - .64 x 3.8 x 15.2 cm. long (1/4" x 1 1/2" x 6" long) - plunger connection
10 rods - 3.6 or .79 cm. diameter (1.4" or 5/16" diameter) 45.7 cm. (18") long with threads and nuts on each end - iron or brass.
20 washers about 2.5 cm. (1") diameter with hole to fit rods
1 rod - .64 x 15.2 cm. (1/4" x 6") with loop end for retaining pivot
6 bolts - .64 x 5.1 cm. long (1/4" x 2" long)

24 screws - 4.4 cm. x #10 - flat head (1 3/4" x #10)
50 - 6.35 cm. (2 1/2") nails
Strip Sheet Metal with turned edge - 6.4 cm. wide, 152.4 cm. long (2 1/2" wide, 72" long)
Small quantity of loose cotton or soft vegetable fiber for caulking seams

Minimum Tools Needed

Tape measure or ruler
Hatchet, Saw
Wood chisel 1.3 or 1.9 cm. wide (1/2" or 3/4")
Screw Driver
Adjustable Wrench
0.64 cm. (1/4") drill, gimlet or similar tool
Draw knife or plane and coping saw (would be useful but not essential)

DETAILS

This model of washing machine should be a decided improvement to conserve clothing over methods now in use in many countries. This is especially true where clothes are beaten or scrubbed on rocks. It will also save a considerable amount of labor. If the cost of this machine is too great for one family, it could be used by several. However, too many users will probably mean severe wear or breakage and competition for times of use.

The machine reverses the principle employed in the usual commercial washer, in which the clothes are swished through the water for various degrees of a circle until the water is moving and then reversed. To keep this machine simple, the clothes stay more or less stationary while the water is forced back and forth through the clothes by the piston action of the plungers. One plunger creates a suction as it rises and the other plunger creates a pressure as it moves downward. Since the principle involves the churning action of the water, the slope at the corners of the machine bottom is important for best action.

The machine needs a rectangular tub for this method of operation. The rectangular box also is easy to build and does not require skilled cooperage methods. In general, any moderately strong wood that will not warp excessively (such as cedro in Central America) will be satisfactory. The sides should be grooved for the ends and bottom of the tub as indicated and bolted with threaded rods extending through both sides with washers to permit it to be drawn tight. The through bolting is important, otherwise, leaks are inevitable.

The size indicated on drawings is considered sufficient for an average family in the U.S. The same principle may be used for a larger or smaller machine provided basic proportions are maintained. The tub should be slightly less than half as wide as it is long to get a proper surge of water. The pistons should be wide enough to move within a couple of inches of each side of the tub. The lever pivot should be high enough to permit the plungers to move up and down several inches without the edge of a lever hitting the edge of the tub. Likewise, rods on the plungers must be long enough to permit plungers to go well into the water so that clothes come completely out of the water at the highest position.

For efficient use of the above washer, several suggestions are made. Fill the washer with fifteen gallons of warm or hot water depending on what is available. Stains should be removed, soap rubbed into areas of garments which come in close contact with the body, and especially dirty clothes should be soaked before placing them in the washer. Shaved soap may be dissolved by heating it in a small quantity of water before adding it to the wash water. A six-pound load of clothes is recommended for best cleaning. Wash at a moderate speed (about fifty strokes per minute) for at least ten minutes or longer if it seems necessary. After washing and rinsing clothes, rinse the washer until clean and then replace the stopper. To prevent the wood from drying out and the washer leaking, add one to two inches of water to the washer when not in use.

Instructions for making washer

Mark and groove sides for end and bottom members.
Drill holes for cross bolts.
Cut off corners and trim ends of side members to length.
Level ends and bottom pieces to fit into groove in side members.
Miter bottom and end members together.
Assemble and bolt.
Cut and install legs.
Caulk seams between ends and bottom members with loose cotton or other vegetable fiber to make seams watertight. If joints to side members are carefully made, they probably will not need caulking.
Bore hole and make plug for draining tub. NOTE: This is shown on side in drawing but it is better in bottom of tub.
Make and install pivot members (upright).
Make and install plunger lever. NOTE: the cross pivot member (round) should be shouldered or notched at each pivot to prevent side movement.
Make plungers and install.

EVALUATION

A pilot model of the machine was made by the U. S. Department of Agriculture in their shops and tested in the Home Economics Laboratory at Beltsville, Maryland. Under test conditions a comparison with standard electric commercial washers was very favorable.

Material From - HOW TO MAKE A WASHING MACHINE
V. C. Pettit and Dr. K. Holtzclaw,
A.I.D.

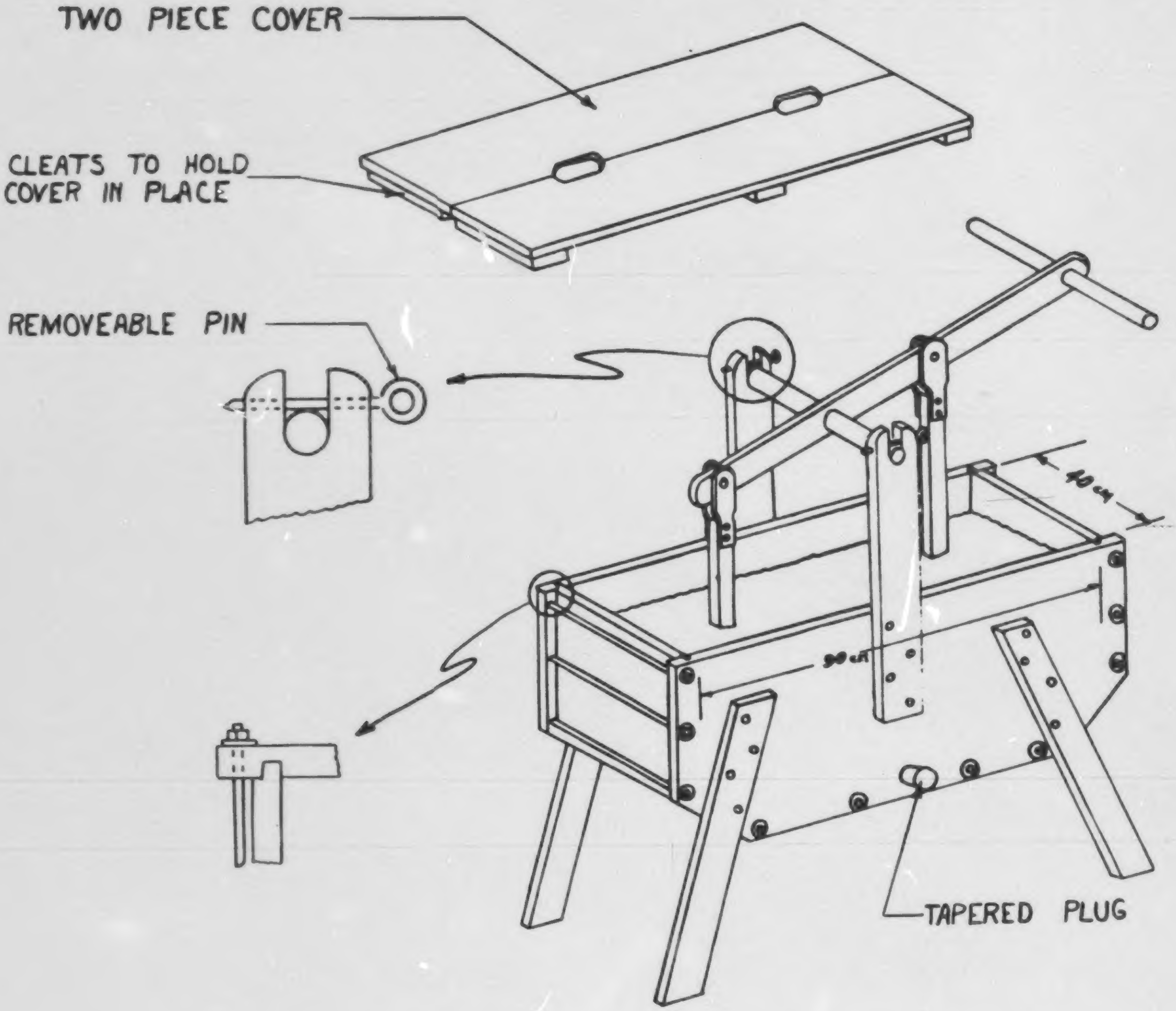
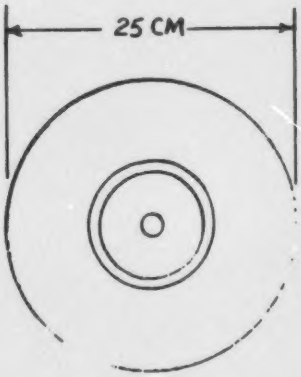
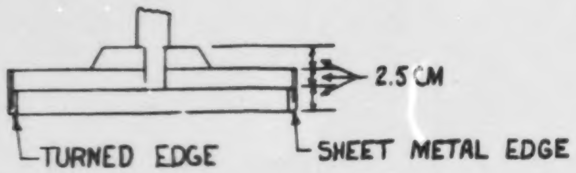

TWO PIECE COVER
CLEATS TO HOLD COVER IN PLACE
REMOVEABLE PIN
40 cm
90 cm
TAPERED PLUG

FIG. 1



TOP VIEW OF PLUNGER


2.5 CM
TURNED EDGE
SHEET METAL EDGE

PLUNGER SECTION

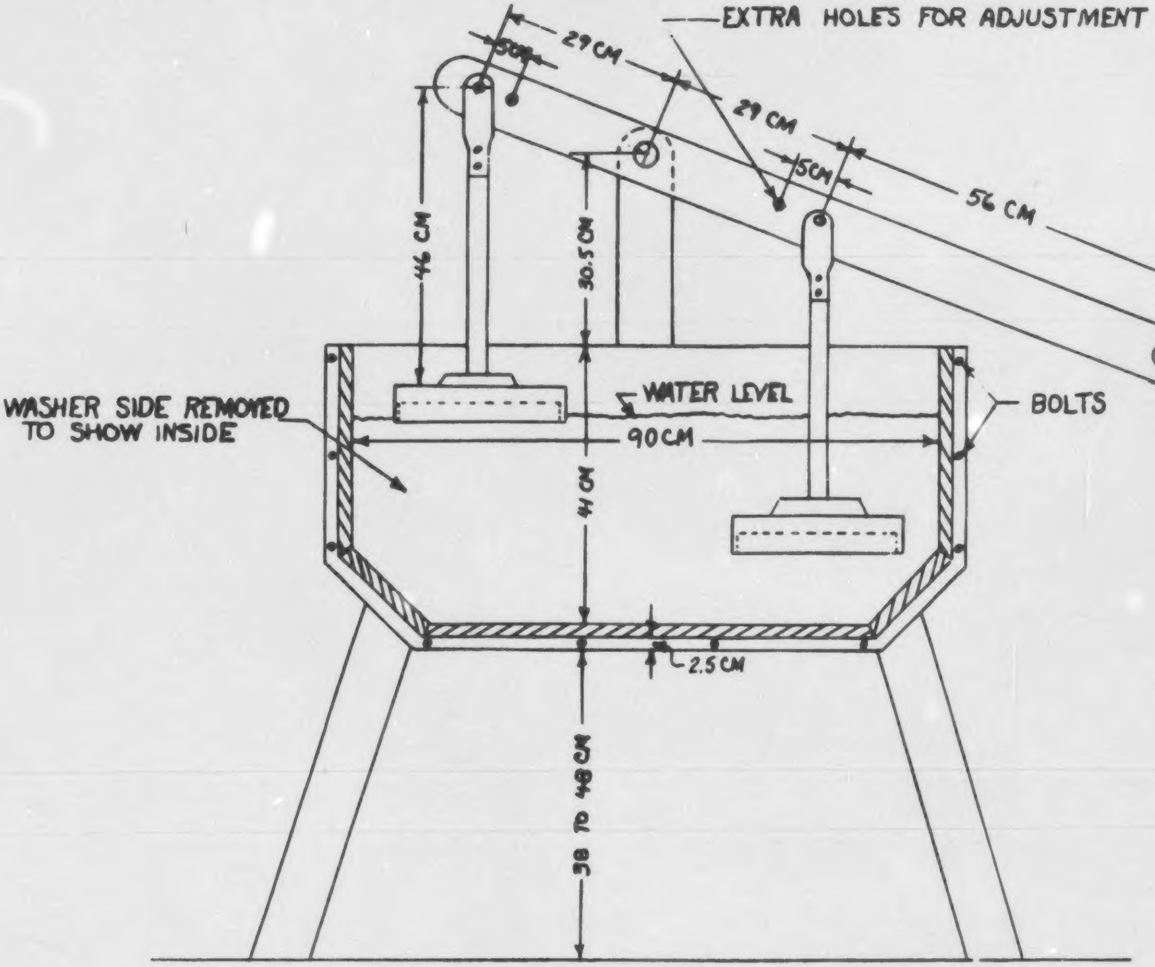

EXTRA HOLES FOR ADJUSTMENT
29 CM
5CM
29 CM
5CM
56 CM
46 CM
30.5 CM
WATER LEVEL
WASHER SIDE REMOVED TO SHOW INSIDE
BOLTS
90CM
44 CM
2.5CM
38 TO 48 CM

FIG. 2

LATRINE FOR VILLAGE USE

ABSTRACT

This low cost water seal latrine slab is a single concrete casting. It requires very little space, is sanitary, odorless, easy to install and maintain, and can be used to produce nightsoil fertilizer.

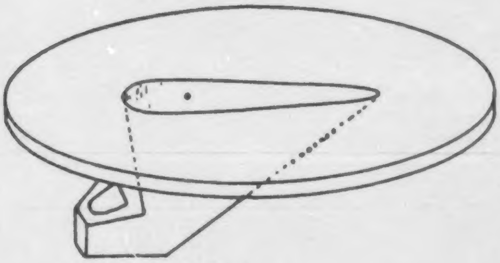


FIG. 1

TOOLS AND MATERIALS

Foot plate form - See Figures 2 and 3
Steel strap iron 2" wide, 9'7" long
3/8" bolt and nut 1" long to hold strap iron form
3/8" bolts 5" long for air vents
Outer form - made of wood detailed on Figure 6.
Inner form - made of wood detailed on Figure 4.
Clay to make water seal form
Cement, sand, stone aggregate up to 1" maximum.

DETAILS

In villages where space is a premium and the soil can absorb the flushing water, this latrine may be worth serious consideration. A 30" diameter hole eight feet deep is covered with a slab. Most soils have sufficient stability to support the slab. Very loose or sandy soils may require some type of lining. Any type of simple superstructure can be fitted over it for privacy. If the nightsoil must be used for fertilizer, this method can be used. After the first six months, a new hole is dug, and the slab moved. The first pit is covered with two feet of dirt. Six months later the nightsoil in the first pit has been converted to essentially non-pathogenic fertilizer and may be used with reasonable safety. Do not use any nightsoil fertilizer that has not been composted at least three months. The slab is moved back to the first hole and the second covered with two feet of dirt.

The latrine can be cleaned with only 1/2 gallon of water. When this is done, there is no odor nor any flies and it stays quite clean. Thus it is easy to use. Villagers must be urged to provide for a sufficient supply of water to be brought and stored at the latrine in a large container (eg. a 4 gallon kerosene tin). A quart container should also be provided. Instructions should be given in the proper method of flushing the latrine. If this is done improperly a large quantity of water will be wasted. Two quarts of water are sufficient to clear the latrine if the water is thrown with a fair amount of force from the narrow end of the latrine.

Installation is so simple that the untrained villager can do it easily. The round one piece construction facilitates moving the slab by rolling it. It is simple to make once the forms and methods are practiced. The materials cost about $1 for a latrine. One trained villager can make three slabs per day, using three forms. The wooden forms cost about $8 each.

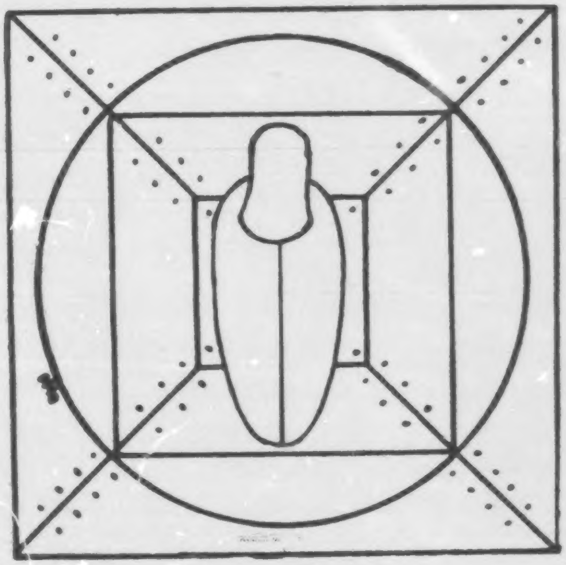


Figure 2
Wood and clay inner form in place on the base seen from above. Steel rim also in position.

A convex foot-plate form about 38" in diameter is made of wood, metal, or concrete. It must be 1" higher in the center then at the edge. See Figure 2.

Figure 3 shows the steel ring and inner form in place on the base. The ring is formed of two inch wide strap iron and fastened with a bolt for easy removal from the concrete slab. The collapsible wooden inner form is detailed in Figure 4.

The inner form has three pieces. Figure 4A shows the outline of the two side pieces of the form. These must be cut from wood 2 1/4" thick. The 18 1/8" sides and 3 3/4" sides stay nearly in contact. A wedge shaped piece of wood shown in Figure 4D holds corner G of the sides one inch apart. The wedge fits along the 9" side. The spring holds the form closed tight against the separation bars while the wedge is inserted and the inner form placed on the base. The dimensions shown for the inner form should only be used as a guide since some inconsistencies have been observed.

Two inches of well mixed concrete (cement 1, sand 2, stone chips 3) is placed in the ring and tamped well to compact it. Next the wooden outer form is set up around the inner liner. See Figures 5 and 6. There should be a clearance of not less than 1/2" between the inner liner and the wooden outer forms. A cement sand mixture (cement 1, sand 2) of plastic consistency is placed in this inner space and compacted. A 3/8" bolt through the outer wood form and into the inner form provides an antisyphon vent and helps to hold the inner form in place. See Figures 8, 10, and 11.

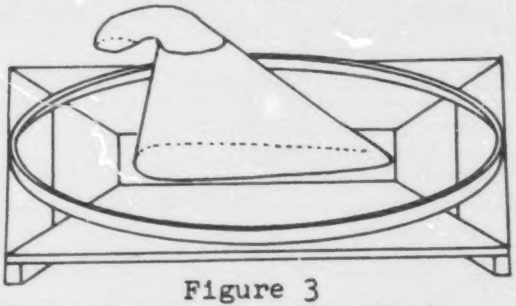
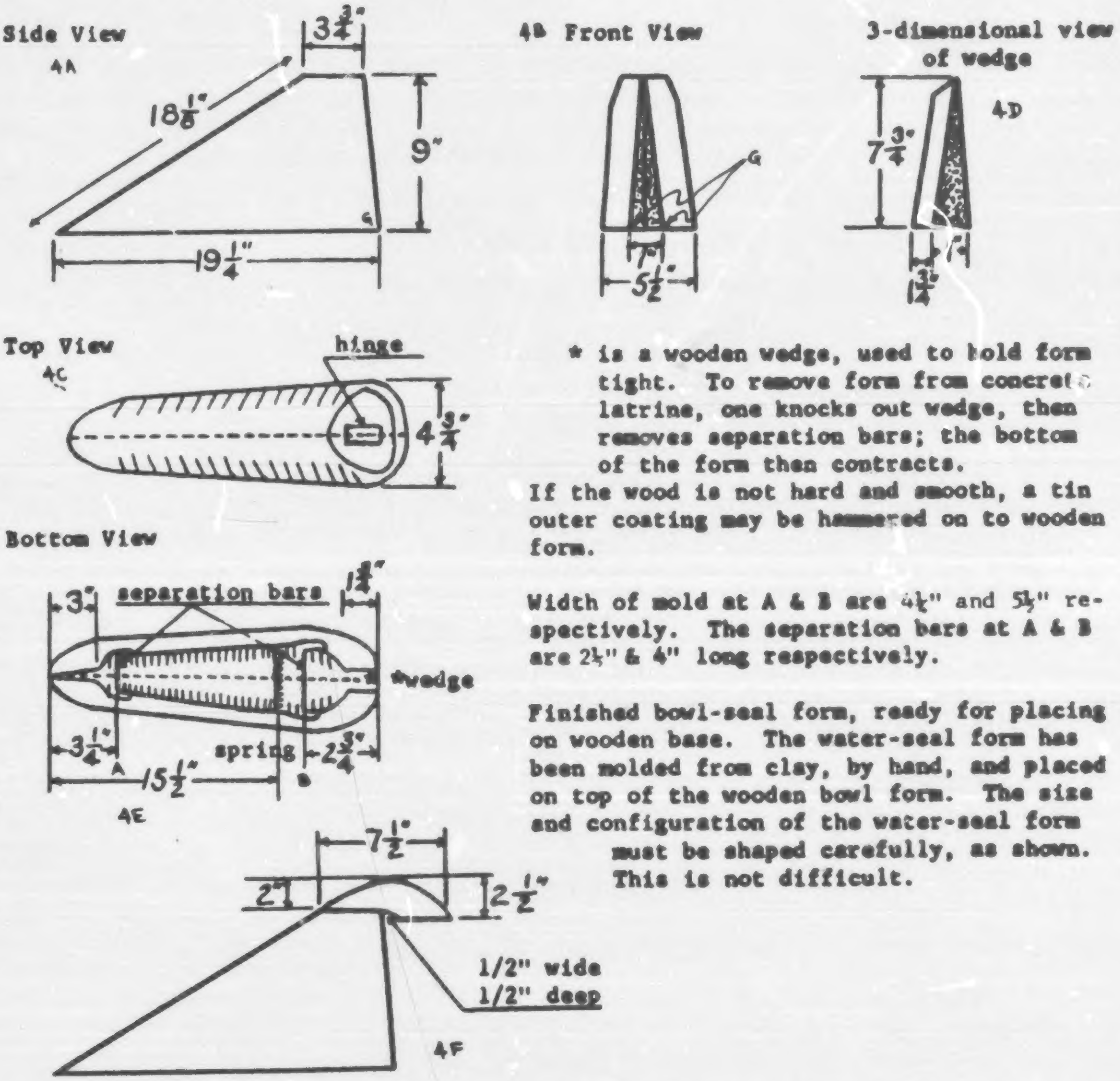


Figure 3
Inner form and steel rim in place on base.

After 48 hours the casting may be placed on blocks. The clay siphon and wooden inner form removed, and a finish of cement plaster added to cover any imperfections. When this is set a final coat of pure cement is put on. If there is any defect in the seal it may easily be repaired by putting a little cement slurry (cement and water in creamy consistency) over the defect and adding at once cement plaster to fill the defect.

EVALUATION

The American Friends Service Committee Barpali project has developed this unit and have many in use. They are teaching a 10 day course in latrine construction to villagers and selling forms at cost to the villagers completing the course. More than 25 persons have completed this course.


Side View
4A
3 3/4"
18 1/8"
9"
G
19 1/4"
4B Front View
G
1"
5 1/2"
3-dimensional view of wedge
4D
7 3/4"
1"
1 3/4"
Top View
4C
hinge
4 3/4"
Bottom View
3"
separation bars
1 3/4"
*wedge
3 1/4"
A
spring
2 3/4"
15 1/2"
B
4E
7 1/2"
2"
2 1/2"
1/2" wide
1/2" deep
4F

* is a wooden wedge, used to hold form tight. To remove form from concrete latrine, one knocks out wedge, then removes separation bars; the bottom of the form then contracts.

If the wood is not hard and smooth, a tin outer coating may be hammered on to wooden form.

Width of mold at A & B are 4½" and 5½" respectively. The separation bars at A & B are 2½" & 4" long respectively.

Finished bowl-seal form, ready for placing on wooden base. The water-seal form has been molded from clay, by hand, and placed on top of the wooden bowl form. The size and configuration of the water-seal form must be shaped carefully, as shown. This is not difficult.

FIGURE 4

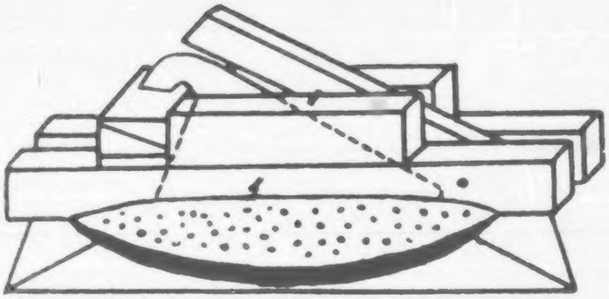


Figure 5
Concrete slab has been poured; part of the exterior sectional mold has been placed in its position.

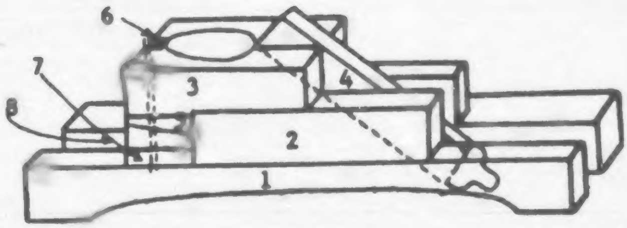


Figure 6
Rough exterior knock-apart mold made to fit around the clay core with a clearance of 1/2" to 3/4".

Wooden constituents of above mold.

1. 4" x 4" x 36" - 2 pieces
2. 3" x 4" x 16" - 2 pieces
3. 3" x 4" x 16" - 2 pieces
4. 3" x 3" x 21" - 1 piece
5. 2" x 5" x 13" - 1 piece
6. 4" x 4" x 1" - 1 piece
7. 5" x 13" x 1" - 1 piece
8. 3" x 4" x 4" - 1 piece

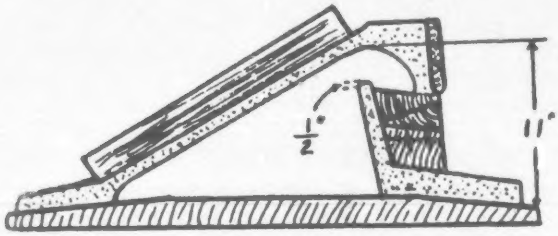


Figure 7
Sectional view after pouring the cement in bowl and trap. Note the concave shape of the base plate.

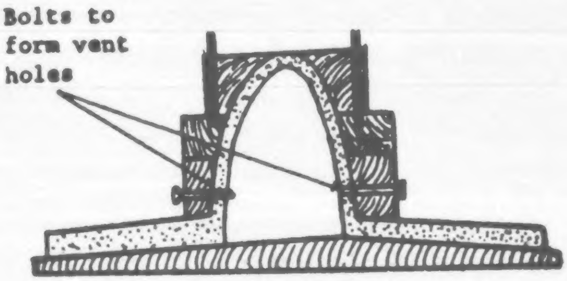


Figure 8
Transverse section of the casting with forms in place.

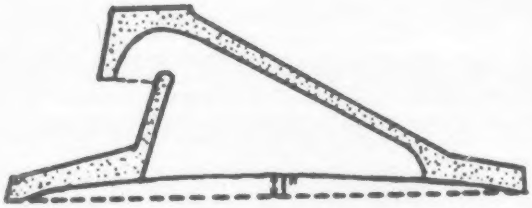


Figure 9
Section of the casting after removal of the forms.

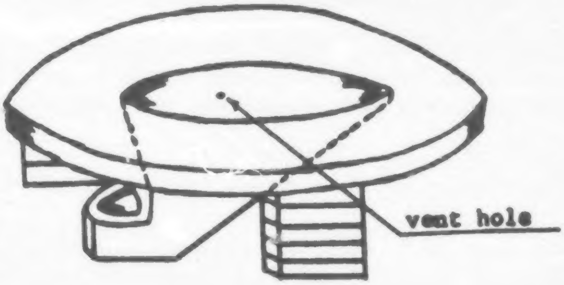


Figure 10
Completed casting set up on bricks where the wooden inner form is removed and clay siphon lining dug out. The final finish of cement plaster and neat cement polish is applied.

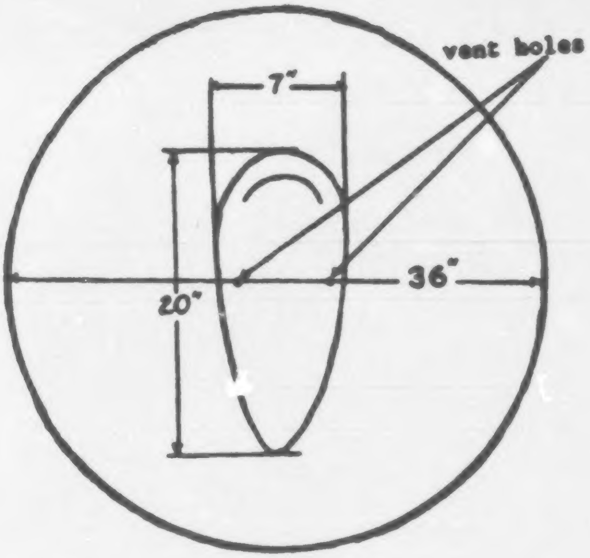


Figure 11
The completed casting from
above showing the dimensions.

Material From - "Latrines for Village Use" Report
on Work in the Field of Sanitary
Engineering, by Edwin Abbott, M.D.

INTRODUCTION TO CONCRETE CONSTRUCTION

ABSTRACT

Concrete is a strong, durable and inexpensive construction material when properly prepared. This brief summary in conjunction with later entries will give you a good introduction to concrete construction.

TOOLS AND MATERIALS

None - general information

DETAILS

After concrete has set, there is no simple non-destructive test to evaluate how strong it is. Therefore, the entire responsibility for making concrete a strong material in accordance with specifications rests with the supervisor on the job and the people who prepare, measure and mix the ingredients, place them in the forms, and watch over the concrete while it hardens.

The most important factor in making strong concrete is the amount of water. Beginners are likely to have too much. See the entry on a slump cone for further details.

The proper proportion of all the materials, designed for the application, is essential. The concrete calculator will help give the proper proportions and amounts for your job.

Properly graded, clean, sharp aggregate and sand is required to make good concrete. When we glue two pieces of paper together, we spread the glue evenly and in a thin layer, and press firmly to eliminate air holes. In concrete, the cement is the glue, and the sand and aggregate the material being joined.

By properly graded we mean that there are not too many of any one size grains or pebbles. Visualize this by thinking of a large pile of stone all 1 1/2" in diameter. There would be spaces between these stones where smaller pebbles would fit. We could add to the pile just enough smaller stones to fill the largest voids. Now the voids would be smaller yet, and even smaller pebbles could fill these holes; and so forth. Carried to an extreme, the pile would become nearly solid rock, and only a very small amount of cement would be needed to stick it together. The resulting concrete would be very dense and strong.

Sharp aggregate and sand is desirable. Smooth, rounded stones and sand can make fairly good concrete, but sharp, fragmented particles work better because the cement as a glue can get a better grip on a rough stone with sharp edges.

It is extremely important to have the aggregate and sand clean. Silt, clay, bits of organic matter will ruin concrete if there is very much present. A very simple test for cleanliness makes use of a clear wide-mouth jar. Fill the jar about half full of the finer material available, the sand and small aggregate, and cover with water. Shake the mixture vigorously, and then allow it to stand for three hours. In almost every case there will be a distinct line dividing the fine sand suitable for concrete and that which is too fine. If the very fine material amounts to more than 10% of the suitable material, then the concrete made from it will be weak.

This means that other fine material should be sought, or the available material should be washed to remove the material that is too fine. This can be done by putting the sand (and fine aggregate if necessary) in some container such as a drum. Cover the aggregate with water, stir thoroughly, and let stand for a minute, and pour off the liquid. One or two such treatments will remove most of the very fine material and organic matter.

Another point to consider in the selection of aggregate is its strength. About the only simple test is to break some of the stones with a hammer. If the effort required to break the majority of aggregate stones is greater than the effort required to break a similar sized piece of concrete, then the aggregate will make strong concrete. If the stone breaks easily, then you can expect that the concrete made of these stones will only be as strong as the stones themselves.

In very dry climates several precautions must be taken. If the sand is perfectly dry, it packs into a smaller space. If you put 20 buckets of bone dry sand in a pile, stirred in two buckets of water you could carry away about 27 buckets of damp sand. The chart does not take this extremely dry sand into account. If your sand is completely dry, add some water to it or else do your measurements by weight instead of volume. The surface of the curing concrete should be kept damp. This is because water evaporating from the surface will remove some of the water needed to make a proper cure. Cover the concrete with building paper, burlap, straw, or anything that will hold moisture and keep the direct sun and wind from the concrete surface. Keep the concrete moist by sprinkling as often as necessary; this may be as often as three times per day. After the first week of curing, it is not so necessary to keep the surface damp continuously.

Mixing the materials and getting them in place quickly, tamping and spading to a dense mixture is important. This is covered on the entry on mixing.

Reinforcing concrete will allow much greater loads to be carried. Later entries describe the proper installation of reinforcing rods. Design of reinforced concrete structures can become too complicated for a person without special training, if they are large or must carry high loads.

Principal Reference - "A Building Guide for Self
Help Project" Department of
Social Welfare and Community
Development, Accra, Ghana.

HAND MIXING CONCRETE

ABSTRACT

Proper mixing of ingredients is necessary to get the highest strength concrete. Hand mixed concrete made with these tools and directions can be as strong as machine mixed concrete.

TOOLS AND MATERIALS

Lumber - 2 pieces
  6' x 3' x 2"
Galvanized sheet metal - 6' x 3'
Nails
Saw, Hammer - -
Or concrete for making a mixing floor.
  (About 10 cubic feet of concrete are needed for an 8' diameter mixing floor made 2" thick with 4" high rim.)

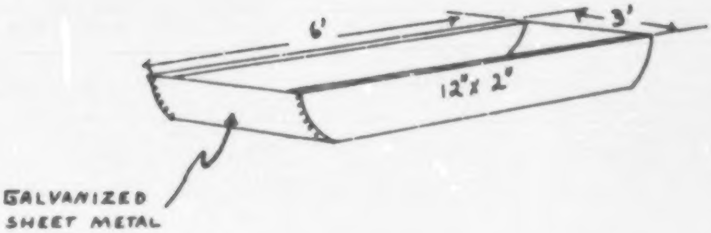


FIG. 1

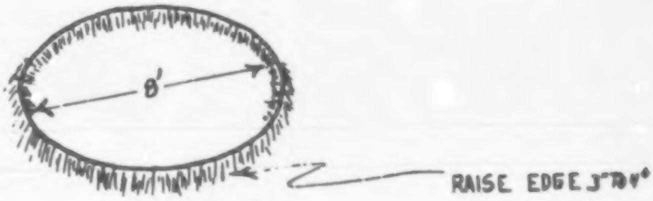


FIG. 2

DETAILS

On many self-help projects the amount of concrete needed may be small or it may be difficult to obtain a mechanical mixer. Under these circumstances hand mixing of the concrete will be necessary and, if a few precautions are taken, the quality of concrete can be made equivalent to that from a mechanical mixer.

The first requirement is a watertight and clean base upon which the mixing can be done. This can be a wood and metal mixing boat (Figure 1) or a simple round floor made of concrete (Figure 2).

The ends of the wood and metal mixing boat are curved to make emptying easier. The raised edge of the concrete mixing floor serves to prevent loss of water from the concrete.

The procedure for mixing is similar to that for mechanical mixers in that the dry materials should be mixed first. As a minimum it is recommended that the pile of stone, sand, and cement be turned completely once. It should be completely turned a second time while the water is being added. Then it should be turned a third time. Anything less than this will not adequately mix all materials. When this last step is completed the mix can be placed as usual.

Correctly placing the fresh concrete in the forms or shuttering is important in making strong structures. The wet concrete mix should not be handled roughly either in carrying to the shuttering or putting into the shuttering. In either case it is very easy, through joggling or throwing, to separate the fine from the coarse material. We have said before that the strongest concrete comes when the various sizes of aggregate and cement are well mixed together . The concrete mix should be firmly tamped into place with a thin (3/4") iron rod.

Be sure to rinse concrete from the mixing boat and tools when finished each day with the work. This will prevent rusting and caking of cement on them for smooth shiney tool and boat surfaces make mixing surprisingly easier, and the tools will last much longer. Also try to keep wet concrete off your skin, for the material is somewhat caustic.

When the shuttering is full the hard work is done, but the process is not finished. The shuttering must be removed and the concrete protected until adequate strength is attained. The hardening action of cement begins almost immediately after the water is added, but the action may not be fully completed for several years.

Concrete reaches the strength used in the designing after 28 days and is strong enough for light loading after 7 days. In most cases the shuttering can be removed from standing structures such as bridges or walls after 4 to 5 days. In small ground supported structures such as street drains it is possible to remove the shuttering within 6 hours of completion provided this is done carefully. Special conditions, usually specified on the plans, may require leaving the shuttering in place for a much longer time.

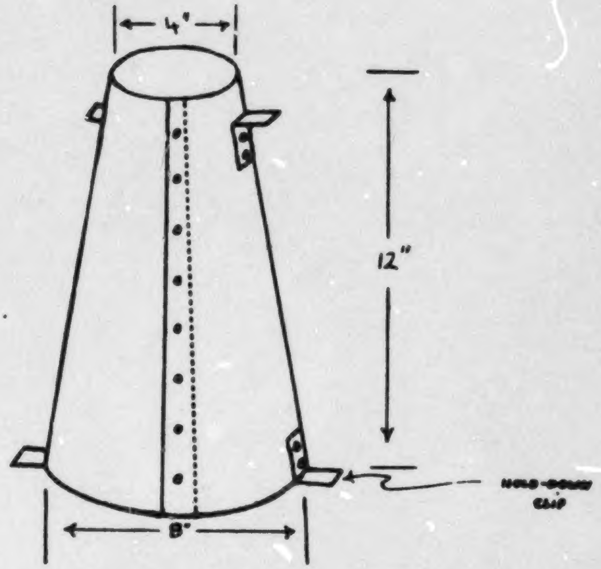
During the early stages of hardening or curing the cement in the concrete continues to need moisture. If there is insufficient water available the cement is unable to complete its job of gluing the aggregate together. Because of this, it is recommended that new concrete be protected from drying winds and the sun, and that the surface of the new concrete be kept damp. For cement floors or open construction a covering of banana or palm leaves will be adequate, but these should be given a sprinkling of water at least once and perhaps twice each day for a period of not less than one week.

Material From - "A Building Guide for Self-Help
Projects," Department of Social
Welfare and Community Development,
Accra, Ghana.

CONCRETE SLUMP CONE

ABSTRACT

The use of this simple device will enable you to determine if the proper amount of water has been added to the mix, which will insure maximum strength in the finished concrete.



TOOLS AND MATERIALS

Heavy galvanized iron
Strap iron - 4 pieces 1/8" x 3" x 1"
16 iron rivets 1/8" diameter x 1/4" long
Wooden dowel 24" long, 5/8" diameter

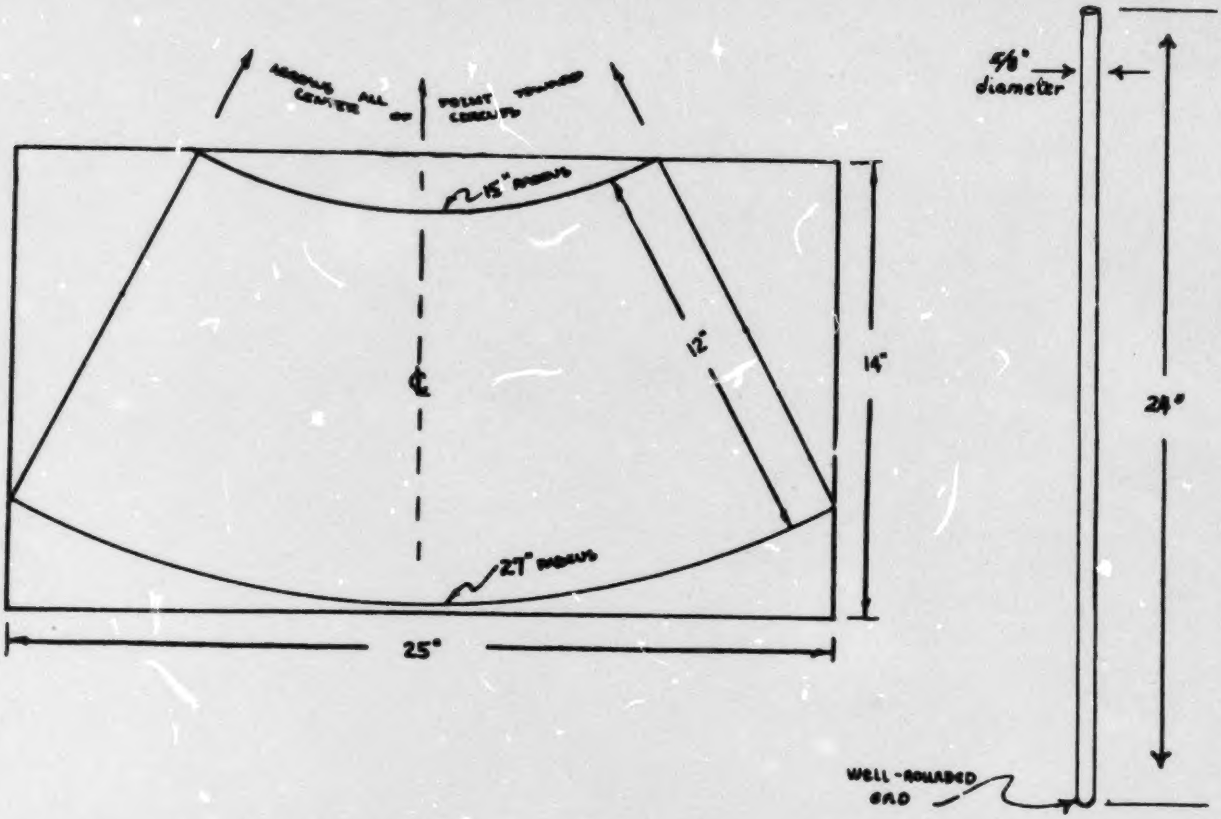
DETAILS

In making reinforced concrete, it is important to have just enough water to make the concrete settle firmly into the shuttering (forms) and around the reinforcing when it is thoroughly tamped.

The easiest way is to look at the mix and at the way the workmen place the wet concrete, If the mix appears soupy and the aggregate shows up clearly in the mix, then it is too wet. At the same time it will be noticed that the workmen dump the mix into the shuttering and do very little tamping because, if they do any amount of tamping, a large amount of water will immediately appear on the surface. The workmen will soon complain if the mix is too dry.

A more accurate method of making a decision on the proper amount of water is to use the slump test. This test requires a small cone made of fairly strong metal and open at both ends. Dimensions of the cone and tamping rod are shown in the sketch. Once this simple equipment is available the slump test becomes very easy. The steps to follow are listed below.

1. Set the slump cone on a smooth clean surface and stand on the hold-down clips at the bottom of the cone.
2. Have someone fill the cone to 1/4 of its height and tamp this layer 25 times.
3. Fill the cone to 1/2 its height and tamp this layer 25 times. Avoid tamping the first layer again.
4. Fill the cone to 3/4 its height and tamp 25 times. Avoid tamping the previous layers.
5. Complete filling of the cone and tamp this layer 25 times.
6. Step off the hold-down clips and lift the cone vertically and very carefully off the concrete.



Since this process will have taken only a few minutes the concrete will still be very soft when the cone is removed and the top will fall to some extent while the sides bulge out. This is called the slump. Obviously, if the mix is too wet the concrete will lose its shape completely and become just a soft pile. A good mix, as far as the water-cement ratio is concerned, will slump about 3" to 4" when the cone form is removed. It is well to keep in mind that dirty or muddy water can cause as much trouble as aggregate with excessive fine materials. Use clean or settled water.

EVALUATION

The slump test is a standard test for evaluating wet concrete. This particular cone and rod has been recommended for village construction projects in Ghana.

Material From - "A Building Guide for Self Help
Projects" Department of Social
Welfare and Community Development
Accra, Ghana; received through
the Near East Foundation.

QUICK SETTING CEMENT

ABSTRACT

Using calcium chloride as an additive in making concrete results in a faster setting product with high initial strength.

TOOLS AND MATERIALS

Ingredients for regular concrete (any Portland cement), and measured amount of calcium chloride.

DETAILS

In some applications a quick setting concrete is very useful. Situations arise when many repeated castings are desired from the same form or mold. Using an accelerator allows parts to be cast about twice as fast as without it.

However, the mixed batch must be put into the forms faster since the concrete setsup sooner. In general, the batches are small for these applications so that fast setting up is no particular trouble. Moreover, the accelerator does not impair the ultimate strength of the concrete.

The accelerator is best added by mixing one pound clean calcium chloride in each quart of water (1/2 kilogram for each litre) and then using this solution as part of the water used in the concrete mix. Use the solution at a ratio of 2 quarts (2 litres) for each bag of cement (94 lbs. or 43 kg.). Mix the concrete in the usual way.

EVALUATION

This is the method recommended by the Portland Cement Association to accelerate the curing of concrete.

Material From - DESIGN AND CONTROL OF CONCRETE MIXTURES, Portland Cement Association, 33 West Grand Avenue, Chicago 10, Illinois.

AIDED SELF-HELP HOUSING ABROAD

For the most of human history, shelter has been provided by the self-help method. Within recent years many governments and peoples have found that when included as a part of the process of economic development, aided self-help methods will contribute greatly to shelter improvement. They are particularly useful in countries where economic development is in its early stages, providing an opportunity for the people to make significant improvements with regard to housing within available resources by using the greatest resource of all, the manpower of the families themselves.

Thus, aided self-help in housing is a method to utilize the many man hours available in the form of heretofore unused leisure time - often enforced leisure because of seasonal unemployment, used in conjunction with some practical form of aid from the state, or others, enabling man to improve his shelter through his own efforts using profitably his spare time to an extent that he never could - alone and unaided.

Perhaps the most important consideration is that this formula permits many governments to not wait for economic development but to proceed now within available resources and to both improve living conditions and also actually contribute to economic development.

The production of better shelter by the aided self-help housing method involves certain responsibilities both on the part of the sponsor of aid and on the part of the families or groups of families who are engaged in the effort to obtain better housing. The sponsor often assists with technical advice in design and construction. Sometimes he arranges for the provision of limited amounts of hard-to-get building materials which may greatly improve the end product. Long term building loans at low interest rates are often necessary. At times the sponsor must assist in arranging for secure land tenure through title or long term lease. Often a combination of some or all of these forms of aid make up an aided self-help housing program. In any event, the sponsor must be organized and equipped to promptly furnish such aid as is deemed necessary and advisable.

The family or group to be aided must assume the responsibility for contributing its labor to the joint effort. Frequently the family gathers together all of the local materials which will be necessary. Usually it repays the cost or a portion of the cost of the aid.

The aided self-help method of improved housing and shelter encourages private ownership of property. It provides constructive opportunity for the use of spare time. It gives the family an opportunity to improve its economic position and its social status in the community. It gives each participating family a stronger interest in the economic and political stability of the country. It adds hope for a better future for many, even though their government has comparatively few resources.

The programs reported in this brochure are only a few of those which are well under way in many places. Each program can learn from the other programs, particularly new ones. This can be done through film and documents, but by far the best way is to call in people who have experience, especially those who have shown imagination and ingenuity in initiating new programs in new places. Technical cooperation in this field is developing rapidly through agreements between individual governments (bilateral); and agreements between international organizations with individual governments (multilateral) and, also, through private contracts.

EXAMPLE OF AIDED SELF-HELP HOUSING

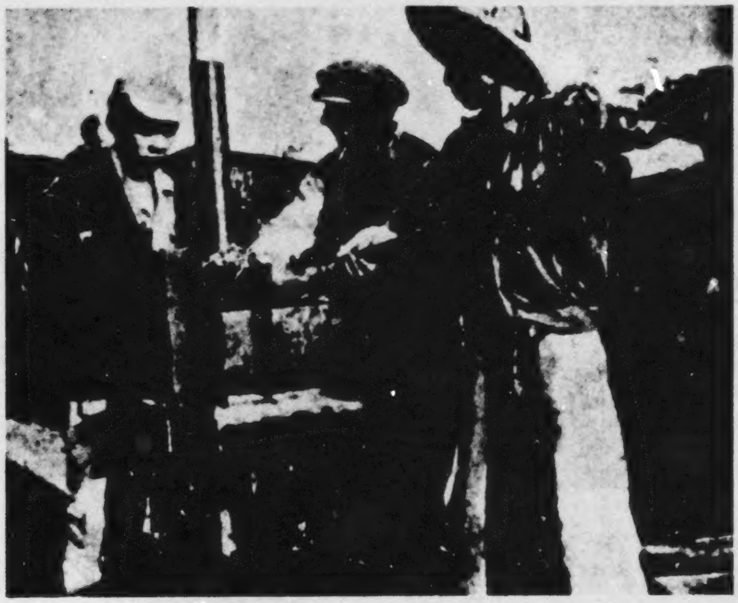
After World War II, while most of Europe was rebuilding, Greece was still fighting against a Communist inspired revolutionary army. When the Communists were defeated late in 1949, immediate reestablishment of Greece's agricultural economy was necessary. Ninety thousand war damaged houses in over 2100 farm villages had to be rebuilt. Funds, labor, materials and transportation were in short supply. At this point, Greece turned to aided self-help housing, as a technique to rebuild for most of the homeless families.

In conference with village leaders and others, the Ministry of Housing and Reconstruction developed a plan so that returning farmers could quickly rebuild their own homes with aid from the Government. The State provided technical advice and the organization to make possible the huge building program. It furnished the scarce (often imported) materials and it delivered these materials to local points of distribution. In addition, the State supplied small amounts of cash, so that the returning farmers could purchase materials which were produced locally, and could employ a limited amount of skilled labor to show them how to rebuild and to assist them in the most difficult phases. Periodic release of aid was on the basis of eligibility and the progress which the family made in reconstruction. Living areas were limited to 300 square feet per family, with provision for future expansion.

The families accepted the responsibility for organizing the reconstruction of their homes. They gathered together the local materials which were available near the site, such as stone, adobe earth and sometimes timber, and purchased locally manufactured products such as lime. They transported the hard-to-get materials supplied by the State from the nearest distribution center to their home site. Then, with the entire family working, they rebuilt their own homes with the advice and sometimes the assistance of the limited supply of skilled labor and government technicians which were available.

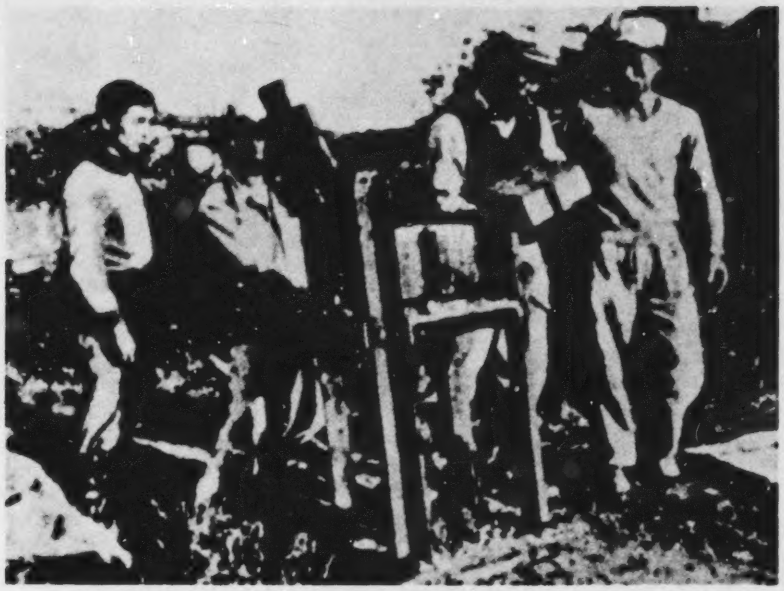
SELF-HELP HOUSING MATERIAL

PRESSED EARTH BLOCKS (10% Cement or Lime Mix)



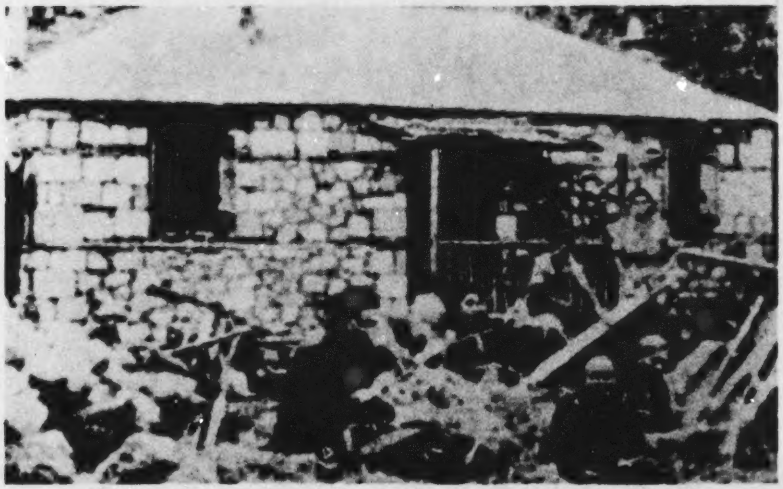
The Dampened Earth Mixture is Placed in a Machine to Form Building Blocks Under Pressure.

Compression of the Stabilized Earth Occurs. Some Authorities Suggest Sinking the Machine in a Small Pit About 18" Deep for Easier Filling and Compressing.



The Block is Removed from the Machine Ready for a Short Period of Drying Before Use.

STONE AND CEMENT SELF-HELP HOMES



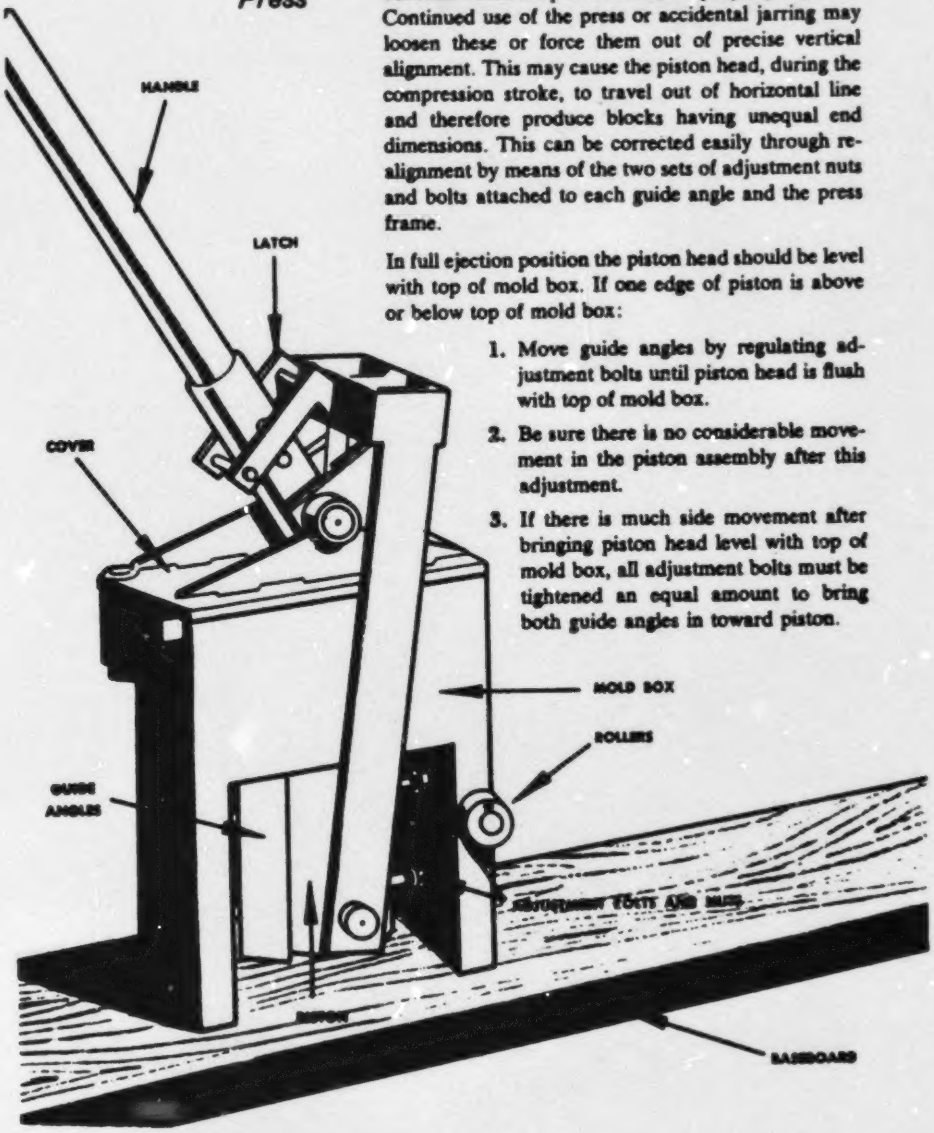
Life Begins Again for the Seventy Thousand Greek War Refugee Families who Rebuilt Their Own Homes Under the Aided Self-Help Housing Program.

EARTH BLOCK PRESS

Building blocks and tiles for small houses, farm buildings, walls, floors, patios, and walks can be made from a simple, portable, low-cost, hand-operated machine using common earth and cement or lime. The all-steel machine, tough and durable, is constructed for long and hard use. Oiling and ordinary care to keep it rust-free are the only maintenance requirements. In many areas earth blocks, if made by the user, cost only about 1/20 as much as conventional building blocks.

Earth blocks are used in the same way as other masonry building materials. In laying them up, apply the same mortar you would normally use. Blocks of heavier densities need no surface protection. They may be painted.

The Cinva-Ram Block Press



ADJUSTING THE PISTON

When the press leaves the factory the two guide angles, between which the piston slides, are properly adjusted. Continued use of the press or accidental jarring may loosen these or force them out of precise vertical alignment. This may cause the piston head, during the compression stroke, to travel out of horizontal line and therefore produce blocks having unequal end dimensions. This can be corrected easily through realignment by means of the two sets of adjustment nuts and bolts attached to each guide angle and the press frame.

In full ejection position the piston head should be level with top of mold box. If one edge of piston is above or below top of mold box:

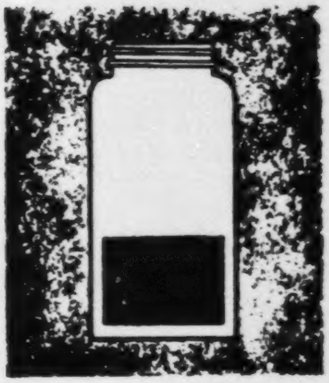
1. Move guide angles by regulating adjustment bolts until piston head is flush with top of mold box.
2. Be sure there is no considerable movement in the piston assembly after this adjustment.
3. If there is much side movement after bringing piston head level with top of mold box, all adjustment bolts must be tightened an equal amount to bring both guide angles in toward piston.

SELECTING THE EARTH

Most earth, when reasonably free from vegetable matter, will make good compressed earth blocks and tiles. Select earth on your property which requires the least amount of digging to meet this specification. The earth from foundation or basement excavations will usually be suitable.

STEPS IN TESTING YOUR EARTH

1. Fill a straight-sided glass jar about one-third full of earth.
2. Add water to fill jar about two-thirds full.
3. Cover jar and shake vigorously until all of the earth is in suspension.
4. Allow earth to settle until you can see the various particle-size divisions. (About 30 minutes.)

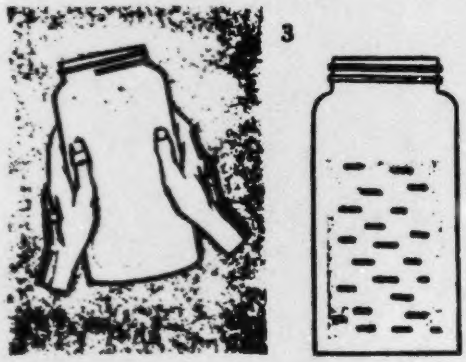


1

Although any earth will make a suitable block, one should attempt to use earth which will make the best block. This is made from earth having particle-sizes from very fine to fairly coarse. The coarse particles should not be less than one-third, nor more than two-thirds of the earth in the jar. The only earth which is not suitable is earth having only one particle-size. However, it is often possible to add sand to make fine-particle earth suitable.

2

3



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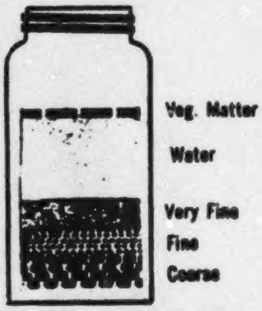
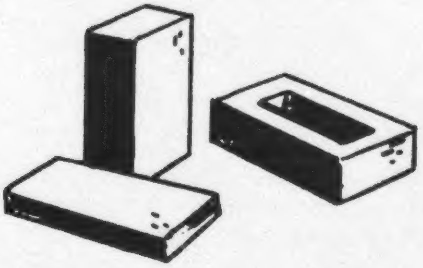




Blocks and Floor Tiles

PREPARING THE EARTH

Only the simplest of implements are required to properly prepare the selected earth.

SCREENING THE EARTH

The selected earth must be screened through mesh having openings of about ¼" square.

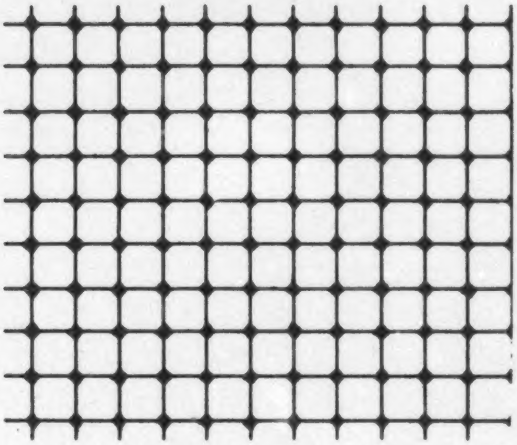
ADDING THE CEMENT

Depending upon the intended use of the blocks and the climatic conditions, excellent results can be obtained with 5 to 10 percent cement. After screening the earth, sprinkle the measured amount of cement evenly and mix thoroughly. Generally, a higher percentage of cement will result in a block having greater resistance to erosion, absorption, and abrasion.

NOTE: *Lime may be substituted for Cement, but in doing so, double the quantity of Lime used and also Double the Curing Time of the Blocks or Tiles.*

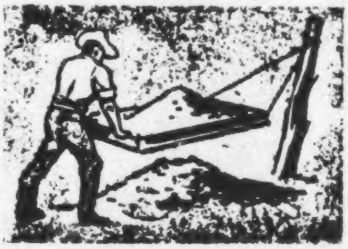
MOISTURE CONTENT

The amount of moisture in the earth mixture is one of the *most important requirements*. A simple test to determine the correct amount of moisture in the mix is to squeeze a ball of the soil mix in your hand. If the ball can be broken in two without crumbling and without leaving any moisture on your hand, the moisture content is correct. Should the mix be too dry, sprinkle small amounts of water evenly and mix thoroughly until it is of the right consistency.

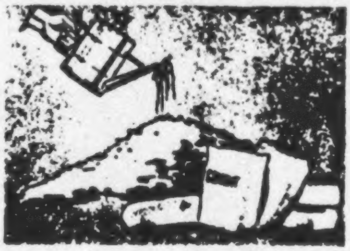


¼" mesh: actual size —

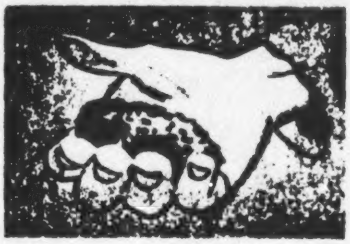
Screening the soil

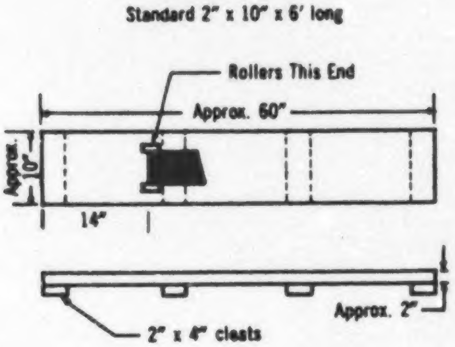


Moistening the soil



determining the dampness





MOUNTING THE PRESS

The press must be attached to a wooden baseboard for necessary stability.

OPERATING THE PRESS

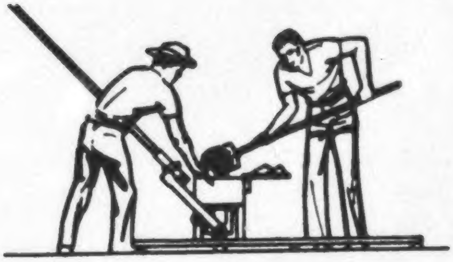
In order to make good compressed earth blocks and tiles, enough earth mix must be loaded into the mold box to require a *hard pull* on the handle. Make a few test blocks and tiles to determine the quantity of your earth mix which must be loaded into the press to give you this adequate, hard pull.

There are three basic operations in making the compressed earth blocks or tiles:

1. Loading the mold box.
2. Compressing the mix.
3. Ejecting the finished product.

Detailed Movements

1. Place the handle in the rest position and open the mold box by swinging the cover horizontally until its stop is reached; then fill the mold box with the prepared earth.
2. Close the mold box, skimming off excess earth, and bring the handle to the vertical position; then release the latch.
3. Pull down the handle until it is parallel with the ground. This applies the necessary pressure to form the block. If the mold box is properly filled, this should require a *"hard pull"*.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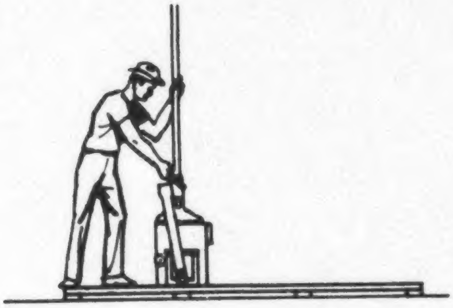
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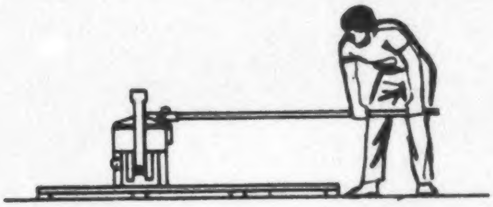
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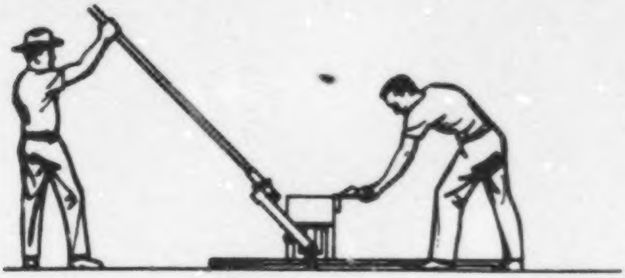


4.

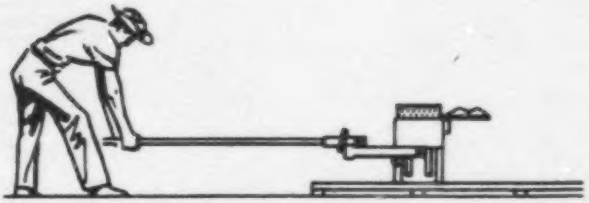
4. Return the handle to the original rest position, swing cover back and open the mold box.

5. Pull down on the handle in the opposite direction until it is parallel with the ground. This ejects the block.

6a *Removing blocks from the press:* Place hands flat at the ends of the block, being careful not to damage the corners or edges and then gently lift the block from the mold box. Place on edge at the curing site.

6b *Removing tiles from the press:* Place one flat hand on top of the tile. Keeping the tile and wooden insert together, slide both off the mold box until the other hand can be placed beneath the insert. Place both on edge at the curing site and then gently separate the insert from the tile.

NOTE: One of the greatest advantages of a compressed earth block or tile is that it can be removed immediately from the press without the use of a pallet.



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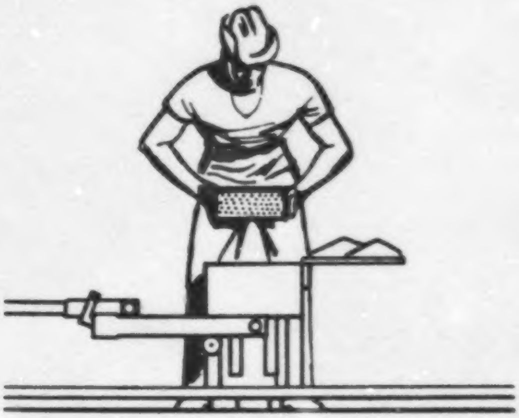
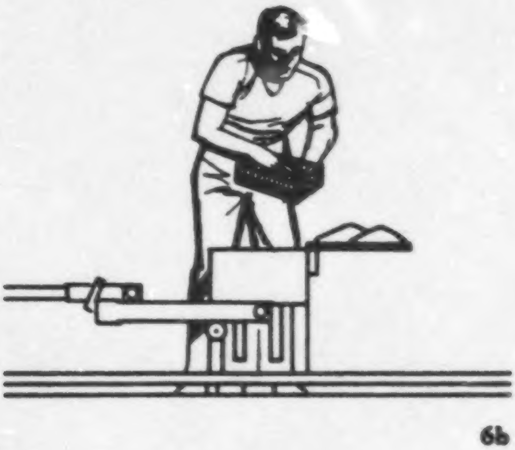
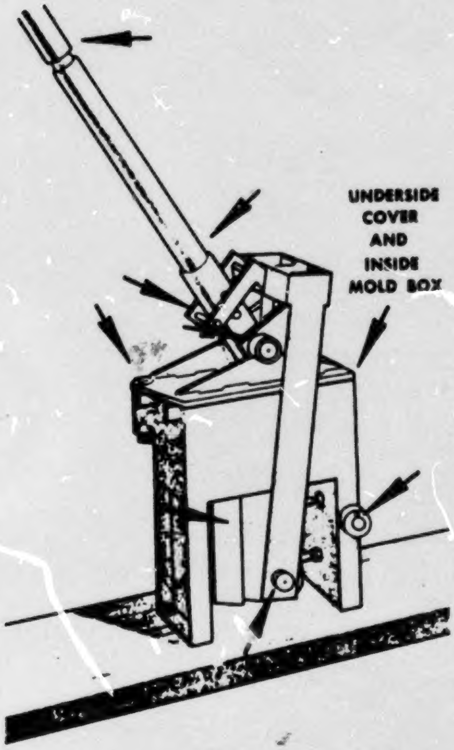


6a



6b



LUBRICATION POINTS

LUBRICATING THE PRESS AND ACCESSORIES

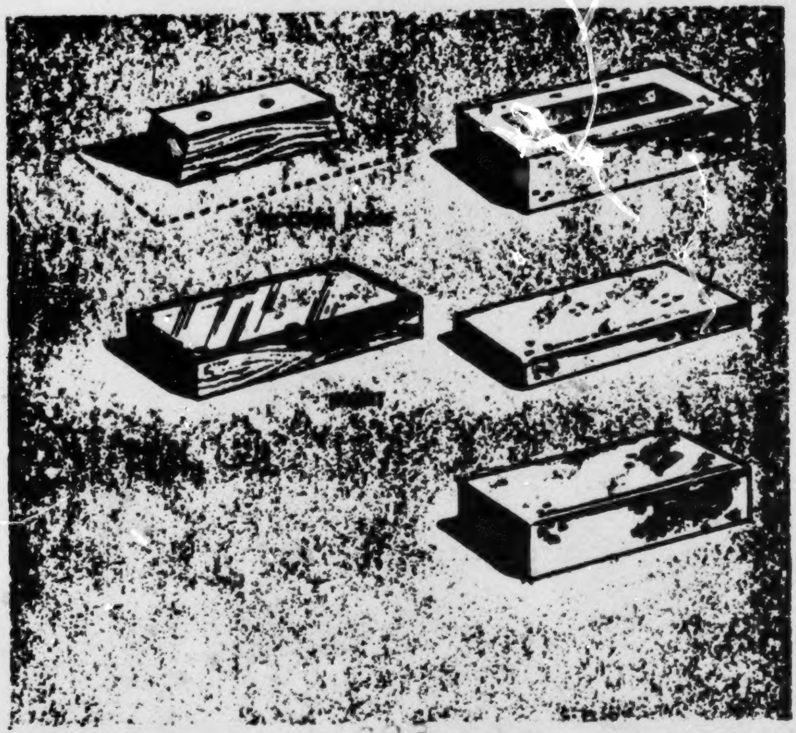
Before and during operation, oil all moving and wearing parts; especially the underside of the steel cover, the inside of the mold box, the metal face of the insert. and the wooden form. FREQUENT oiling of the form and insert DURING OPERATION will prevent finished blocks and tiles from sticking when removing them from the press. A light coating of oil over the entire press after operation or during storage for long periods of time will keep it free from rust.

MAKING BLOCKS AND TILES

To make a solid block, do not use the wooden form or the insert. Remove both from the mold box. If the wooden form is attached to the piston head, it can be released by removing the two screws at the top of the wooden form.

To make a semi-hollow block, attach only the wooden form to the piston head by means of the two screws supplied.

To make a tile, place only the insert at the bottom of the mold box, *Metal face up*.



NOTE: Each Cinva-Ram comes equipped with 5 inserts to fabricate blocks for field drains, grilles, lintels, shelf-supports, conduits and pipes, as well as semi-hollow, tile, and half blocks.

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